STUDIES

FROM THE

Yale Psychological Laboratory

EDITED BY

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1902

VOL. X.

YALE UNIVERSITY
NEW HAVEN, CONN.

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

CONTENTS

RESEARCHES ON RHYTHMIC ACTION

BY

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The present investigation of rhythmic action was begun in 1898 and ended in 1901.

I. ARHYTHMIC ACTION.

The term 'arhythmic action' is used here to mean a series of movements executed at intentionally irregular intervals. In the following experiments we have to observe how irregularly such a series of movements can be performed.

In the preliminary experiments I used the LUDWIG kymograph and two MAREY tambours, so arranged that the recording point of one of the tambours drew a line on the smoked surface of the cylinder of the kymograph.[1] The subject was required to hold the lever connected with the other tambour between his thumb and index finger, and, his eyes being closed, to move it up and down successively at irregular intervals at a rather rapid rate.

The experiments were made on three subjects; a specimen record is shown in Fig. 1. The height of the curve corresponds to the amplitude

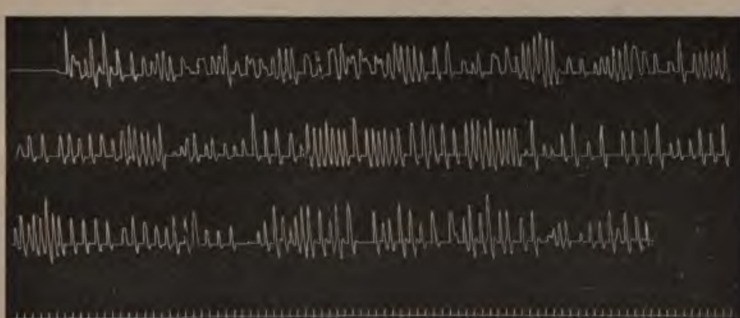

FIG. 1.

of the movement, and therefore to the intensity of the exerted muscular energy, while the horizontal distance indicates the length of the time

[1] Details of the arrangement are given in Exercise VIII of SCRIPTURE, *Elementary course in psychological measurements*, Stud. Yale Psych. Lab., 1896 IV 108, Fig. 16.

between the successive movements. The line at the bottom indicates fifths of a second. It was observed in this record as well as in the others: (1) that there is constantly recurring tendency to repeat equal intervals in succession; (2) that the same intensity of the muscular energy is also often repeated; and (3) that the weak and strong intensities often alternate. The attempt at irregular action thus shows a persistent tendency to revert to action regular in time and intensity.

The records obtained in the above experiments show the characteristics of arhythmic action under the various circumstances for the various subjects. Accurate measurements of the length of the intervals can be better obtained by another method. A Deprez marker and a key with a break contact were put in series in a 1^{am} current. The pointer of the marker was rested lightly against the smoked surface of the cylinder of the kymograph. The subject was asked to tap the key at intervals as irregular as possible, the slowest speed of the two successive beats being limited to about one second. He was seated comfortably before the appa-

Record I. Subject S.

1	2	3	4	5	6	7	8	9	10	11	12
55	36	27	23	14	13	13	39	32	27	28	11
13	14	15	16	17	18	19	20	21	22	23	24
12	12	12	12	12	15	12	19	27	14	14	12
25	26	27	28	29	30	31	32	33	34	35	36
14	13	14	15	13	12	14	22	12	11	17	20
37	38	39	40	41	42	43	44	45	46	47	48
22	34	31	38	59	15	18	12	40	33	30	40
49	50	51	52	53	54	55	56	57	58	59	60
14	15	14	15	13	15	15	16	14	14	14	15
61	62	63	64	65	66	67	68	69	70	71	72
14	16	34	34	32	28	19	10	15	15	30	15
73	74	75	76	77	78	79	80	81	82	83	84
14	14	15	27	15	15	32	17	22	14	14	16
85	86	87	88	89	90	91	92	93	94	95	96
15	16	16	15	32	15	15	15	15	15	16	15
97	98	99	100	101	102	103	104	105	106	107	108
15	15	16	16	15	15	15	34	26	25	15	16
109	110	111	112	113	114	115	116	117	118	119	120
14	15	14	14	15	15	15	15	15	14	20	16
121	122	123	124	125	126	127	128	129	130	131	132
16	22	16	11	14	11	42	24	42	18	14	16
133	134	135	136	137	138	139	140	141			
19	14	17	20	19	17	16	32	56			

Unit of measurement, $\Sigma = 0.01^s$. First line indicates the serial number of the period Second line indicates the length of the period in hundredths of a second.

ratus and his eyes were closed during the experiments. The speed of the kymograph was made fast enough so that the interval between the two successive beats could be measured with sufficient accuracy.

For obtaining the time line the JACQUET graphic chronometer was used, with the pointer vibrating five times a second; one-fifth of a second being divided into twenty equal parts, the one-hundredth part of a second could be used as a unit of measurement.

The subjects of the experiments were as follows: S, an instructor at Yale University; U, a student; and J, the steward of the psychological laboratory.

The results of the experiments are given in the accompanying RECORDS, in which the figures in the first horizontal line indicate the serial number of the period and those in the second horizontal line the length of the successive periods, $\Sigma = 0.01^s$ being the unit.

RECORD II. SUBJECT J.

1	2	3	4	5	6	7	8	9	10	11	12
31	14	14	12	12	12	22	16	23	16	54	12
13	14	15	16	17	18	19	20	21	22	23	24
38	14	14	15	14	29	10	16	18	32	15	13
25	26	27	28	29	30	31	32	33	34	35	36
20	38	18	60	14	16	16	16	16	16	16	34
37	38	39	40	41	42	43	44	45	46	47	48
15	34	34	34	15	17	17	18	18	16	33	16
49	50	51	52	53	54	55	56	57	58	59	60
20	16	16	16	46	16	14	16	15	16	45	14
61	62	63	64	65	66	67	68	69	70	71	72
16	55	16	19	14	30	18	16	23	22	42	42
73	74	75	76	77	78	79	80	81	82	83	84
18	18	18	14	24	44	17	30	18	38	16	16
85	86	87	88	89	90	91	92	93	94	95	96
18	14	16	14	14	14	13	14	16	16	16	28
97	98	99	100	101	102	103	104	105	106	107	108
16	30	34	19	16	14	14	40	42	18	34	46
109	110	111	112	113	114	115	116	117	118	119	120
14	16	16	16	16	12	14	16	15	14	14	16
121	122	123	124	125	126	127	128	129	130	131	132
18	33	16	20	16	14	14	18	22	15	16	15
133	134	135	136	137	138	139	140	141	142	143	144
14	14	15	14	14	20	13	20	19	11	11	16
145	146										
12	30										

Unit of measurement, $\Sigma = 0.01^s$. First line indicates the serial number of the period. Second line indicates the length of the period in hundredths of a second.

RECORD III. SUBJECT U.

1	2	3	4	5	6	7	8	9	10	11	12
12	13	20	20	16	16	16	16	10	10	16	19
13	14	15	16	17	18	19	20	21	22	23	24
12	22	11	12	22	31	37	20	12	17	16	16
25	26	27	28	29	30	31	32	33	34	35	36
15	15	15	14	13	10	18	40	40	27	16	30
37	38	39	40	41	42	43	44	45	46	47	48
46	35	40	12	18	19	27	25	30	25	40	32
49	50	51	52	53	54	55	56	57	58	59	60
14	20	28	33	27	35	30	29	38	32	14	15
61	62	63	64	65	66	67	68	69	70	71	72
15	15	13	17	32	37	38	20	18	12	30	30
73	74	75	76	77	78	79	80	81	82	83	84
26	25	15	36	35	40	23	26	33	45	30	13
85	86	87	88	89	90	91	92	93	94	95	96
20	20	14	14	15	16	15	15	14	28	48	28
97	98	99	100								
15	20	28	33								

Unit of measurement, $\Sigma = 0.01^s$. First line indicates the serial number of the period. Second line indicates the length of the period in hundredths of a second.

The records show the following facts: (1) there are repetitions of equal or about equal periods; (2) the unequal periods, which occur after or in the middle of a group of the repeated equal periods, are, in many cases, simple multiples of the latter; (3) the periods from 12 to 17 are most frequent; (4) rhythmic alternations of long and short intervals also occur.

These facts seem to indicate that arhythmic movements have a constant tendency to become rhythmic, notwithstanding the voluntary effort of the subject to execute the movements at irregular intervals. The subjects of the experiments invariably agreed in confessing that the arhythmic tappings required strenuous effort and that the performance was very fatiguing.

II. INFLUENCE OF AUDITORY AND VISUAL SENSATIONS ON RHYTHMIC ACTION.

The purpose of the experiments in this section was to determine how the regularity of the rhythmic movement is influenced by the auditory and visual stimuli.

As there are two different forms of rhythmic action, the one "regu-

lated" and the other "free,"[1] the experiments were made separately on both forms.

A. Regulated rhythmic action.

The function of the auditory or visual stimuli in regulated rhythmic action is to give us the objective standard of the period in coincidence with which we execute our movements. Of the two kinds of sensations, auditory and visual, which one is the more favorable for the regularity of the movements?

It was very important that the movements of the finger should be registered without producing any sound audible to the subject. A special key was made of a small piece of steel spring about 55^{mm} long and 4^{mm} in width fastened tightly at one end to a wooden block. A platinum point put on the block made contact with a similar point on the spring. A slight touch of a finger at the free end of the spring wire would break the electric circuit at the platinum point. Used inside a muff, the very faint click which it produced was rendered imperceptible to the ear.

For producing the auditory stimuli a pair of discharging points connected to a spark coil were used. The two brass rods were put in a horizontal line with a distance of about 2^{mm} between them and connected to the poles of the secondary circuit. When the primary circuit was broken a sound was produced by the spark. The points were put behind a black screen, so that the spark could not be seen by the subject.

For producing the visual stimuli without sound a GEISSLER tube was connected with the secondary coil. In order that the faint sound produced in the tube when the current passes through it might be made inaudible, the tube was put in a wooden box with a glass window in front.

The discharging points and the GEISSLER tube were connected by means of a double switch to the secondary current of the spark coil.

A simple brass contact on a WUNDT contact apparatus[2] attached to the LUDWIG kymograph was used for breaking the contact of the primary current of the spark coil at a regular interval. The break of the contact produced either the sound of the spark at the discharging points or the flash in the GEISSLER tube. By turning the switch either of the two stimuli could be used as desired. A DEPREZ marker connected in series with the key in 1^{am} current recorded on the smoked surface the moment of the beat of the finger. A fork of 10 complete vibrations a second

[1] SCRIPTURE, *Observations on rhythmic action*, Stud. Yale Psych. Lab., 1899 VII 102.

[2] WUNDT, Physiol. Psychol., 4. Aufl. II 424, Leipzig 1893.

SCRIPTURE, *Elementary course in psychological measurements*, Stud. Yale Psych. Lab., 1896 IV 127.

registered its vibrations by a pair of MAREY tambours.[1] Each of the waves could be readily divided into ten equal parts; this made it possible to use $\Sigma = 0.01^s$ for the unit of measurement.

The point where the stimulus occurred was carefully determined, and a "zero-line" was drawn by moving the drum up and down.

In many respects the arrangements resembled those used in Exercise XII of the Yale laboratory course.[2]

The subject of the experiment was seated in a silent room and was asked to beat time on a noiseless key in coincidence either with the sounds of the sparks or with the flash of light from the GEISSLER tube. The records were taken in a adjoining room. The accessory communication between the two rooms was made by means of telegraph sounders.

The two sets of the trials, one with the sounds and the other with the flashes, were always made on the same occasion, the order of the trials being changed alternately. The experiments were made on two subjects; of these D was a student, and S an instructor at Yale University. The time interval of the signals was one second.

The results of different series of experiments for a period of 1^s are shown in Tables I and II, in which the average constant error is the average deviation of the beats from the corresponding signals. When the former comes after the latter, it is marked with the positive sign, and when it comes before, it is marked with the negative sign. The average constant error is thus:

$$\Delta t = \frac{x_1 + x_2 + \cdots + x_n}{n},$$

where x_1, x_2, $\cdots$, x_n are the lengths of time by which the finger beat occurs *after* the stimulus (negative values indicating *before*). In the column headed "Number of measurements," the number of the beats recorded is given. The column headed "Number of positive deviations" shows the number of the cases in which the beats came after the signal and the column headed "Number of negative deviations," that in which the beats came before. The probable error, which is an indication of the regularity of the movements, is obtained by the formula:

$$p = \tfrac{2}{3}\sqrt{\frac{(\Delta t - x_1)^2 + (\Delta t - x_2)^2 + \cdots + (\Delta t - x_n)^2}{n - 1}},$$

where Δt is the average constant error, x the individual deviation, and n the number of measurements.

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[1] LANGENDORFF, Physiologische Graphik, 134, Leipzig und Wien 1891.

[2] SCRIPTURE, *Elementary course in psychological measurements*, Stud. Yale Psych. Lab., 1896 IV 127.

It will be observed in comparing Tables I and II that the probable errors of the movements with the sounds are smaller than those with the flashes. With the subject D, the probable errors for sounds vary from 0.9^{Σ} to 2.2^{Σ} and for flashes from 1.2^{Σ} to 3.4^{Σ}. With the subject S the probable errors for the sounds vary from 1.0^{Σ} to 1.7^{Σ}, for the flashes from 1.2^{Σ} to 6.9^{Σ}. The averages of the probable errors are: for D, sounds 1.7^{Σ}, flashes 1.9^{Σ}; for S, sounds 1.3^{Σ}, flashes 3.2^{Σ}.

TABLE I.

Regulated rhythmic action with sounds at intervals of 1^s.

Subject.	Average constant error.	Number of measurements.	Number of positive deviations.	Number of negative deviations.	Probable error.
D	— 9.0	16	0	16	2.0
	— 6.4	16	0	16	1.4
	— 5.5	20	0	20	2.0
	— 5.5	20	0	20	0.9
	— 2.0	20	2	18	2.2
	— 1.9	20	5	15	1.9
	— 6.6	20	0	20	1.6
	— 2.5	20	2	18	1.6
S	— 12.4	16	0	16	1.7
	— 7.2	16	0	16	1.2
	— 5.2	20	0	20	1.2
	— 3.4	18	0	18	1.0
	— 5.7	20	0	20	1.2
	— 3.9	20	0	19	1.2
	— 7.1	20	0	20	1.2
	— 5.8	20	0	20	1.3

Unit of measurement, $\Sigma = 0.01^s$.

TABLE II.

Regulated rhythmic action with flashes at intervals of 1^s.

Subject.	Average constant error.	Number of measurements.	Number of positive deviations.	Number of negative deviations.	Probable error.
D	— 13.7	16	0	16	3.4
	— 5.6	16	0	16	1.3
	+ 0.2	20	10	6	1.2
	+ 0.2	20	2	17	1.3
	— 2.3	20	0	20	1.2
	+ 2.3	20	3	17	2.8
	+ 8.1	16	16	0	1.8
	— 4.8	16	0	16	2.0
S	— 3.8	16	11	3	6.9
	— 3.6	16	0	15	1.3
	— 7.9	20	0	20	1.5
	— 7.0	20	0	20	1.9
	— 7.7	20	0	20	2.1
	+ 0.5	20	12	8	5.4
	+ 23.3	20	20	0	5.6
	— 5.4	20	20	0	1.2

Unit of measurement, $\Sigma = 0.01^s$.

The results show that the rhythmic movements regulated by auditory sensations are more regular than those regulated by visual sensations. It may be also noticed that most of the beats of the finger come before the sounds and also before the flashes, but more often in the case of sounds. With the subject D the beats with sounds come before the signals 143 times out of 152, with the flashes 108 times out of 144. With the subject S all 150 beats with sounds came before the signals, with the flashes only 63 out of 152. This fact agrees with JOHNSON's[1] experiments, in which it was observed that all his subjects anticipated the signals in beating time with the strokes of an electric sounder.

B. Free rhythmic action.

In regulated rhythmic action the sensations are produced by some external means, and the length of the interval is beyond the control of the subject. In free rhythmic action these sensations are produced as the accompaniment or consequence of the movement, and the length of the interval depends on the speed of the movement as chosen by the subject himself.

The present experiments on free rhythmic action were carried on in the two different series of trials: (1) free rhythmic action with and without auditory sensations, and (2) free rhythmic action with and without visual sensations.

1. Free rhythmic action with and without auditory sensations.

The experiment consisted in tapping on a noiseless key. The small "strap" key used in this experiment was made of an elastic brass strip, *B*, 46^{mm} long and 9^{mm} wide, mounted on a wooden block, *E*; a brass stop, *C*, kept the free end of the spring from rising more than 4^{mm} from the block. A slight pressure on the button, *A*, at the free end of the strap forced it nearer the block and broke its contact with the brass stop. Platinum points, *D*, were used to ensure good contact between the strap and the stop.

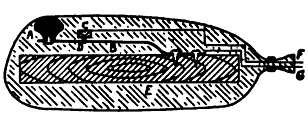

FIG. 2.

The key was put in a rubber bag and packed in felt so that the sound was rendered absolutely inaudible; the key was thus an absolutely noiseless one. The wires, *F*, *G*, projected from the bag. A spot on the surface of the rubber bag under which the button of the key was situated was marked with a sign. It indicated the point where the tapping was to be

[1] JOHNSON, *Researches in practice and habit*, Stud. Yale Psych. Lab., 1898 VI 51.

hand at what he considered to be a constant interval. The rate of the done. The adjustment of the key was such that the slightest touch broke the circuit.

The same discharging points that were used in the preceding experiments were fixed to two binding posts and mounted on a wooden block. All apparatus conditions were kept constant. The points were put behind a curtain so that the subject would hear the sounds of the sparks without seeing the flashes.

The general plan of the arrangement is shown in the accompanying diagram (Fig. 3). The noiseless key, *K*, with condenser, *C*, around the break was placed in the primary current, *P*, of a spark coil, *B*. The secondary coil, *S*, was connected in series with the metallic registering point of a PFEIL marker, *M*, and the discharging points, *J*, so that a break of the primary circuit would produce a spark on the time-line at the point of the marker and also between the discharging points at the same moment. In this way the movement of finger on the key, breaking the primary current, resulted in a sound of the spark between the discharging points and a record on a smoked drum, *D*, simultaneously.

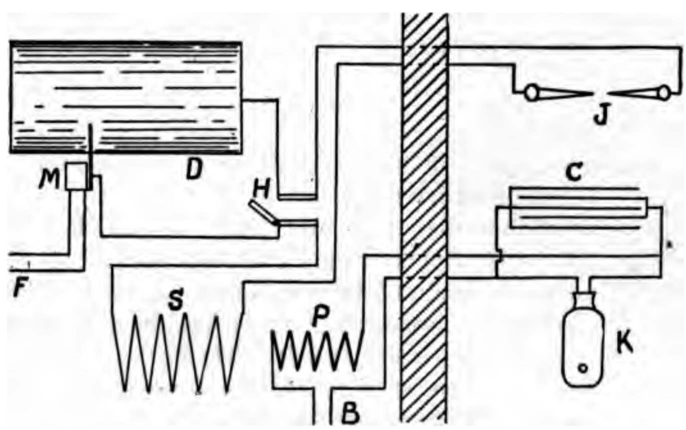

FIG. 3.

A switch, *H*, was put in the secondary circuit around the discharging points. When the switch was closed, the short circuit prevented sparks at the discharging points, and the tapping on the key was not followed by the sound of the spark, although still recorded on the drum. A time-line was drawn on the drum by the marker, *M*, run by a 100 v. d. fork.

The key and the discharging points were placed in a special quiet room, the rest of the apparatus was in another room.

The subject with closed eyes beat time with the index finger of his right

movement was left entirely to his own choice. Two sets of the experiments, one with sounds and the other without sounds, were tried at the same time of day under as nearly the same conditions as possible. The order of trials of the two sets was alternated every time. From the record of one set of the beats 10 (in exceptional cases 9 or 8) successive periods were counted.

As an indication of the amount of the regularity of the movements, the probable error was used as in the preceding experiments. The formula for the immediate probable error is

$$p = \tfrac{2}{3}\sqrt{\frac{v_1^2 + v_2^2 + \cdots + v_n^2}{n - 1}},$$

where $v_1, v_2, \cdots, v_n$ are the differences between the individual measurements of the interval and the average, and n is the number of measurements. The relative probable error is

$$r = \frac{p}{a}$$

where a is the average; r indicates the relation of the amount of irregularity to the length of the interval.

The subjects of the experiments were four: M and Y, students of psychology; H, a student of law; and C, the laboratory mechanic.

Table III. shows the results of the experiments. For the sake of comparison, the results on the two kinds of movement, the one with and the other without sounds, are put side by side. The figures arranged in the same horizontal line are the results of the experiments taken on the same occasion. The unit of measurement was $\sigma = 0.001$.

A comparison of the corresponding probable errors in the same horizontal line will show that those of the free rhythmic movement with the sound are almost always smaller than those of the movement without the sound. This holds true for both the simple and the relative probable errors. In the case of the subject C the errors for the movement with the sound are always smaller than those of the movement without the sound. In the three other subjects M, H and Y, the case where the errors for the movement with the sound are larger than those of the movement without the sound occurs only once for each. The general conclusion may be drawn that free rhythmic movement with the sound is more regular than that without the sound.

It can be also noticed in the table that the length of the periods in general is shorter in the movements with the sound than in those without the sound. This is specially shown in the cases of the subjects

M and Y in which the periods with the sound are always shorter than those without the sound. This is probably due to the fact that the time interval marked off by the muscle, joint and skin sensations and the auditory sensations appears longer to the subjects than the equal interval which is marked off by the former group alone, and that therefore the subject tends to shorten the former.

TABLE III.

Free rhythmic action.

Subject.	With sound. Average time.	p	$\frac{r}{100}$	Without sound. Average time.	p	$\frac{r}{100}$
M	515	10.5	2.3	533	21.2	4.0
	523	11.2	2.1	559	19.6	3.4
	526	9.7	1.8	673	19.7	2.9
	500	13.8	2.7	528	7.0	1.3
	543	14.7	2.7	575	20.6	3.5
	519	11.3	2.1	550	22.0	4.1
	517	10.6	2.0	567	11.5	1.9
	502	4.7	0.9	523	14.8	2.8
H	428	10.4	2.4	360	18.5	5.1
	335	15.3	4.5	379	30.8	8.1
	349	15.0	4.3	388	14.0	3.6
	387	13.8	3.5	389	22.6	5.8
Y	803	14.8	1.8	856	29.5	3.4
	748	17.0	2.3	911	29.4	3.2
	1333	33.4	2.5	1347	42.7	3.1
	1305	32.6	2.5	1362	32.0	2.4
	709	25.3	3.5	713	28.2	3.9
	618	7.8	1.7	646	12.4	1.9
C	544	7.9	1.4	583	12.0	2.5
	561	9.3	1.6	581	16.6	2.8
	683	15.0	2.2	594	20.4	3.4
	791	12.0	1.5	763	20.8	2.7
	945	14.4	1.5	799	25.5	3.6
	958	14.2	1.4	1074	32.7	3.0
Average			2.3			3.4

Unit of measurement, $\sigma = 0.001^s$.

2. Free rhythmic action with and without visual sensations.

The apparatus and method of experimenting were mainly the same as before. The noiseless flash of the spark was substituted for sound. In order to render the sound of the spark inaudible, the discharging points were put in the inner of two concentric glass tubes; the sparks could be seen by the subject but not heard.

The results of the experiments are given in Table IV. The average of the intervals is, in general, the average of ten individual measurements, but

in exceptional cases the average of 8. The unit of measurement was $\sigma = 0.001^s$. The results of the two sets of the trials, the one with and the other without the flash of the spark, which were taken at the same time of the day, are put in the same horizontal line.

TABLE IV.

Free rhythmic action.

Subject.	With flash. Average time.	p	$\frac{r}{100}$	Without flash. Average time.	p	$\frac{r}{100}$
C	849	16.0	1.9	880	33.3	3.8
	929	27.3	2.9	883	13.3	1.5
	945	24.0	2.5	1187	35.3	2.9
	1156	32.7	2.8	1171	29.3	2.5
	1012	34.0	3.3	1049	25.3	2.3
	1044	19.0	1.7	1147	25.3	2.2
M	591	20.7	3.4	591	22.0	3.7
	537	16.0	2.9	572	9.3	1.6
	542	12.0	2.2	583	9.7	1.8
	563	17.0	3.1	573	1.7	2.9
	528	12.0	2.3	587	13.3	2.3
	540	12.7	2.6	583	18.0	3.1
	537	10.7	2.0	519	16.0	3.1
	514	20.7	4.2	536	19.3	3.4
	510	17.3	3.4	491	19.1	2.1
	504	18.0	3.6	504	15.3	3.0
Y	487	20.0	4.1	501	13.0	2.5
	569	14.9	2.6	521	13.3	2.5
	523	10.6	2.3	497	8.0	1.8
	490	15.3	3.1	481	12.0	2.7
	696	12.0	1.7	744	18.7	2.5
	642	18.0	2.8	691	11.3	1.6
	991	23.3	2.4	1038	28.7	2.7
	915	32.7	3.5	1008	21.3	2.1
	755	30.0	3.9	891	41.3	4.6
	792	16.0	2.0	715	21.3	3.5
	785	20.0	2.5	847	34.6	4.1
	764	22.0	2.0	721	27.3	3.8
Average			2.8			2.7

Unit of measurement, $\sigma = 0.001^s$.

A comparison of the corresponding relative errors in Table VII shows that in the two subjects C and Y, the number of cases is about the same in which the probable error is smaller for either one of the two kinds. The conclusion may be drawn that the presence of the flash of the spark with the beat of the finger does not affect the regularity of the rhythmic movement in a constant manner; sometimes the presence of the flash increases the regularity of the beats, but the reverse is quite as often true.

In the subject M, however, the number of the cases where the movement with the flash has the smaller probable error is only 3, while the

number of reverse cases is 6 out of 10. This result seems to indicate that the influence of the visual sensation on the regularity of the measurement is here not neutral, but active in destroying it.

III. Intensity and interval in rhythmic action.

The principal purpose of the following experiments was to determine how a change of intensity in the rhythmic movements affects the length of the interval.

Ebhardt,[1] working on the same problem, made two series of experiments. In the first series the tapping was done on an electric key, and in the second on a piano with electric connections. The records were taken in both cases on a kymograph. The results showed that the interval following the emphasized beat was lengthened as compared with that which followed the unemphasized beat. In Ebhardt's experiments the tapping was accompanied by the noise of the instrument.

A. Beats without noise.

The noiseless key described above (p. 8) was put with the Pfeil marker in series in a 1^{am} current. The metallic point of the marker was connected with one pole of the secondary coil of a spark coil, the other pole being connected to the base of the recording drum. The current from a 100 v. d. fork was sent through the primary coil. In this way the beats were recorded by checks in the line on the drum; these were divided by the sparks into equal spaces, each of which corresponded to $\frac{1}{100}$ of a second. The subject tapped with his finger (generally with the index finger of the right hand) on the noiseless key, according to the following schemes:

(*a*) 1′–2, 1′–2, 1′–2, ...
(*b*) 1–2′, 1–2′, 1–2′, ...
(*c*) 1′–2–3, 1′–2–3, ...
(*d*) 1–2′–3, 1–2′–3, ...

where the beat to be emphasized is marked with the sign ′. In the scheme 1′–2, for instance, the subject was asked to emphasize every first beat of the rhythmic group, but he had, at the same time, to try to keep always a uniform interval between two successive beats, not only between 1′ and 2, but also between 2 and 1′ although he was to think of the groups as in pairs 1′–2, not 2–1′. The speed of the movements was left to the choice of the subject.

[1] Ebhardt, *Zwei Beiträge zur Psychologie des Rhythmus und des Tempo*, Zt. f. Psych. u. Physiol. d. Sinn., 1898 XVIII 99.

The experiments were made on M. M., assistant in the psychological laboratory; C. W., a student of physics; and J. K., a student of philosophy.

Table V gives the results of the experiments on the scheme 1′–2. The averages of the intervals 1′ to 2 and 2 to 1′, obtained from each single series of experiments, are put in the same horizontal line. The unit of measurement is $\sigma = 0.001^s$. The ratio between the averages of the two intervals is given in the last column, the average for 1′ to 2 being taken as the unit.

The table shows that all the subjects made the interval 1′ to 2 longer than 2 to 1′; that is, the interval following the emphasized beat was made longer than that which follows the unemphasized beat.

The results of the experiments with the scheme 1–2′ are given in Table VI. It will be seen that the average length of the intervals 2′ to 1 is in all the cases longer than that of 1 to 2′.

A comparison of Tables V and VI shows the fact that the lengthening of the interval following the emphasized beat is more marked with the scheme 1–2′ than with 1′–2. The average ratios of the two intervals in the two different rhythmic schemes are:

	1′–2	1–2′
	1′ to 2 : 2 to 1′	1 to 2′ : 2′ to 1
C. W.	1.00 : 0.94	0.82 : 1.00
M. M.	1.00 : 0.93	0.90 : 1.00
J. K.	1.00 : 0.91	0.90 : 1.00

The relative lengths of the long and short intervals are not the same in the two different schemes; the interval which comes after the emphasized beat is comparatively longer in 1–2′ than in 1′–2. The same fact was observed by EBHARDT.[1]

Why is the interval following the emphasized beat lengthened more in one rhythmic scheme than in the other? This can be accounted for by assuming another factor, besides emphasis, that lengthens the period of the movements. It is due, as already pointed out by EBHARDT, to the formation of the rhythmic group. Rhythmic movements with grouping differ in their nature from those without grouping. The latter is merely a series of repeated movements at a uniform interval, in which every single movement is regarded as a coördinate unit. In the former, a series of the movements is divided into groups containing a certain number of movements as their content, and each of such groups is regarded as a unit.

EBHARDT supposed that at the end of the rhythmic group a suspension

[1] EBHARDT, *Zwei Beiträge zur Psychologie des Rhythmus und des Tempo*, Zt. f. Psych. u. Physiol. d. Sinn., 1898 XVIII 99.

TABLE V.

Beating on noiseless key.

Scheme: 1′–2.

Subject.	Average of intervals from 1′ to 2.	Average of intervals from 2 to 1′.	Number of measurements.	Ratio 1′ to 2 : 2 to 1′.
C. W.	574	549	10	1.00 : 0.94
	595	589	10	1.00 : 1.00
	635	529	10	1.00 : 0.81
	538	503	10	1.00 : 0.98
	628	559	10	1.00 : 0.89
	641	632	10	1.00 : 0.99
M. M.	662	613	10	1.00 : 0.92
	601	578	10	1.00 : 0.96
	599	533	10	1.00 : 0.89
	633	614	10	1.00 : 0.97
	685	639	10	1.00 : 0.93
	708	670	10	1.00 : 0.99
J. K.	693	613	10	1.00 : 0.97
	716	681	10	1.00 : 0.96
	659	585	10	1.00 : 0.89
	602	536	10	1.00 : 0.89
	584	532	10	1.00 : 0.91
	669	654	10	1.00 : 0.83
	656	613	10	1.00 : 0.93
	647	593	10	1.00 : 0.92
	681	662	10	1.00 : 0.97

Unit of measurement, $\sigma = 0.001^s$.

TABLE VI.

Beating on noiseless key.

Scheme: 1–2′.

Subject.	Average time from 1 to 2′.	Average time from 2′ to 1.	Number of measurements.	Ratio 1 to 2′ : 2′ to 1.
M. M.	549	573	10	0.96 : 1.00
	650	723	10	0.90 : 1.00
	682	746	10	0.92 : 1.00
	632	758	10	0.84 : 1.00
J. K.	661	747	10	0.89 : 1.00
	702	745	10	0.94 : 1.00
	575	634	10	0.90 : 1.00
	502	564	10	0.90 : 1.00
	582	706	10	0.83 : 1.00
	538	593	10	0.91 : 1.00
	579	588	9	0.98 : 1.00
	573	669	4	0.86 : 1.00
	557	585	10	0.95 : 1.00
	663	748	10	0.89 : 1.00
C. W.	597	661	10	0.90 : 1.00
	561	829	10	0.68 : 1.00
	618	773	10	0.80 : 1.00
	520	564	10	0.92 : 1.00
	665	721	10	0.86 : 1.00
	517	621	10	0.83 : 1.00
	548	736	10	0.75 : 1.00

Unit of measurement, $\sigma = 0.001^s$.

of attention takes place and that the moment of suspension can be considered as a dead time, which is to be added to the length of the foregoing group. We are not certain whether such suspension of the attention takes place or not. But it seems to be more probable that we have a tendency to insert some "pause" between two successive rhythmic groups, in order to mark off the groups distinctly from each other. The "pause" is to facilitate the formation of the groups.

We may suppose then that a certain length of "pause" was inserted between the groups in the scheme 1′–2 as well as in 1–2′, and that because the interval from 2′ to 1 of the scheme 1–2′ is lengthened both by the "pause" and the emphasis, it is made considerably longer than the time from 1 to 2′, whereas in the scheme 1′–2 the time from 1′ to 2 is lengthened only by the emphasis, while the time from 2′ to 1 is lengthened by the "pause," whereby the difference between 1–2′ and 2′–1 is not so great.

TABLE VII.

Beating on noiseless key.

Scheme 1′–2–3.

Subject.	Average time from 1′ to 2.	Average time from 2 to 3.	Average time from 3 to 1′.	Number of measurements.	Ratios 1′ to 2 : 2 to 3 : 3 to 1′.
M. M.	722	445	638	7	1.00 : 0.62 : 0 88
	790	462	780	10	1.00 : 0.58 : 0.99
J. K.	708	657	617	10	1.00 : 0.93 : 0.87
	724	655	650	10	1.00 : 0.90 : 0.90
	974	968	949	9	1.00 : 0.99 : 0.97
	757	739	752	10	1.00 : 0.97 : 0.99
	734	592	620	10	1.00 : 0.81 : 0.85
	663	646	634	10	1.00 : 0.99 : 0.96
C. W.	621	590	574	10	1.00 : 0.96 : 0.92
	624	614	621	10	1.00 : 0.99 : 1.00
	586	589	578	10	1.00 : 1.00 : 0.99
	601	595	562	10	1.00 : 0.99 : 0.95
	553	541	508	10	1.00 : 0.98 : 0.92
	559	546	550	10	1.00 : 0.98 : 0.95
	575	559	541	10	1 00 : 0.97 : 0.94

Unit of measurement, $\sigma = 0.001^s$.

The results of the experiments on the scheme 1′–2–3 are given in Table VII. The ratios of the average intervals were found here by assuming the time from 1′ to 2 as the unit.

The table shows again that the interval following the emphasized beat is longer than that which follows the unemphasized one.

The lengthening of the interval between the groups is not remarkable here. Although with the subject M. M. the interval 3 to 1′ is longer than 2 to 3, with J. K. the two intervals are about equal and with C. W. 3 to

1′ is in a majority of cases shorter than 2 to 3. This is due perhaps to the fact that for the last two subjects the "pause" between the groups was very short. Moreover, it is probable that the two subjects made the second member of the group stronger than the third, the beats being made not exactly in the scheme 1′–2–3, but in a manner something like 1″–2′–3 with the consequence that the interval following the second beat on account of the emphasis became longer than that following the third.

The results of the experiments on the scheme 1–2′–3 are given in Table VIII. The ratios of the average intervals were obtained by regarding 2′ to 3 as a unit. It will be observed here that the interval 3′ to 1 is very constantly longer than 1 to 2′.

TABLE VIII.

Beating on noiseless key.

Scheme: 1–2′–3.

Subject.	Average time from 1 to 2′.	Average time from 2′ to 3.	Average time from 3 to 1.	Number of measurements.	Ratios 1 to 2′ : 2′ to 3 : 3 to 1.
M. M.	371	714	668	9	0.52 : 1.00 : 0.93
	404	601	642	7	0.67 : 1.00 : 1.07
J. K.	689	719	713	10	0.96 : 1.00 : 0.99
	802	940	842	10	0.85 : 1.00 : 0.90
	761	862	806	9	0.88 : 1.00 : 0.93
	739	780	769	10	0.91 : 1.00 : 0.98
	685	740	765	10	0.93 : 1.00 : 1.08
	890	927	909	9	0.96 : 1.00 : 0.98
	704	730	762	10	0.97 : 1.00 : 1.04
C. W.	638	614	639	10	1.04 : 1.00 : 1.04
	730	744	733	10	0.98 : 1.00 : 0.98
	746	758	753	9	0.98 : 1.00 : 0.99
	567	581	466	8	0.98 : 1.00 : 0.80
	465	485	491	10	0.96 : 1.00 : 1.02
	515	517	525	10	0.99 : 1.00 : 1.02

Unit of measurement, $\sigma = 0.001^s$.

When 2′ to 1 is compared to 3 to 1, sometimes the latter is longer than the former, although in a majority of the cases the former is longer than the latter. This fact indicates that there is a strong tendency to lengthen the interval between the groups. If 1–2′–3 is compared to 1′–2–3, we find that there is a remarkable difference between the two rhythmic schemes in regard to lengthening of the intervals between the groups. The interval 3 to 1′ of the scheme 1′–2–3 is not so much lengthened as 3 to 1 of 1–2′–3. In other words the "pause" between the groups is longer in 1–2′–3 than in 1′–2–3. This fact indicates that the length of the "pause" is not the same in all rhythmic forms. It depends, probably, on

the amount of difficulty of the formation of the rhythmic groups. The more difficult the formation of the groups, the longer is the pause. In the case 1′–2–3 with the first beat of a group emphasized, the group can be easily marked off from the preceding or the following groups, and the rhythmic group can be formed, without lengthening very much the interval between them. But the case is different with the scheme 1–2′–3, where neither the first nor the last beat of a group is emphasized. Of the two similar beats one comes at the end of a group and the other at the beginning of the next group; the two successive groups can be marked off distinctly only by lengthening the interval between them.

B. Drum beats.

The same apparatus was used as before except that an ordinary snare drum 30^{cm} in diameter and 50^{cm} in height was substituted for the noiseless key. Both ends were covered with vellum. In order to make the electric connection with this instrument, the touch key (Fig. 4), mounted

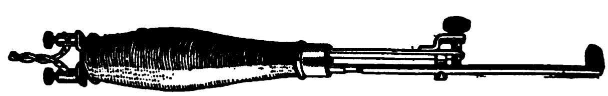

FIG. 4.

on a wooden block, was fastened to the outer wall of the drum, so that the rubber button of the key was in contact with the vellum of the lower side. When the drum was struck at the upper end, the movement of the lower end broke the electric contact of the key. The key was put in series with the PFEIL marker. The beat on the drum could thus be recorded on the smoked paper. The metallic point of the marker was placed in the secondary circuit of a spark coil whose primary circuit was interrupted by a 100 v. d. fork as in preceding experiment.

The subject was required to stand before the table on which the drum was put and to beat on it with a stick according to prescribed rhythmic schemes. For the beating the arm movement of the right hand was used instead of the finger movement of the previous experiments.

Table IX gives the results of the experiments with the scheme 1′–2. In obtaining the ratios of the average intervals the time from 1′ to 2 is regarded as the unit.

The table shows that the time 1′ to 2 is longer than 2 to 1 in almost all cases. With the subject C. W., 1′ to 2 is always longer than 2 to 1′. With J. K., 1′ to 2 is longer than 2 to 1′ in all except one case out of 9. With M. M. again 1′ to 2 is longer than 2 to 1′ except in one case out of 10.

TABLE IX.

Drum beats.

Scheme : 1′–2.

Subject.	Average time from 1′ to 2.	Average time from 2 to 1′.	Number of measurements.	Ratio 1′ to 2 : 2 to 1′.
C. W.	681	658	10	1.00 : 0.97
	724	714	10	1.00 : 0.97
	750	736	10	1.00 : 0.98
	747	727	10	1 00 : 0.97
	774	753	10	1.00 : 0.97
	791	739	10	1.00 : 0.92
	788	755	10	1.00 : 0.96
	798	766	10	1.00 : 0.96
	782	744	7	1.00 : 0.95
J. K.	766	739	9	1.00 : 0.96
	659	620	10	1.00 : 0.94
	705	724	10	1.00 : 0.99
	737	732	10	1.00 : 0.99
	746	741	10	1.00 : 0.93
	776	726	10	1.00 : 0.98
	777	762	10	1.00 : 0.98
	701	684	10	1.00 : 0.98
	724	707	10	1.00 : 1.03
M. M.	817	793	10	1.00 : 0.97
	866	816	10	1.00 : 0.93
	856	799	10	1.00 : 0.93
	868	819	10	1.00 : 0.94
	852	797	10	1.00 : 0.93
	740	703	10	1.00 : 0.95
	825	783	9	1.00 : 0.95
	670	657	10	1.00 : 0.98
	699	681	10	1.00 : 0.97
	660	664	10	1.00 : 1.01

Unit of measurement, $\sigma = 0\ 001^s$.

Table X gives the results of the experiments with the scheme 1–2′. In obtaining the ratio of the two intervals 2′ to 1 is regarded as the unit. It will be observed from the table that again the interval which follows the emphasized beat is longer than that which follows the unemphasized one. The average time from 1 to 2′ is always shorter than 2′ to 1.

If we compare the schemes 1′–2 and 1–2′ the comparative length of the time from 2′ to 1 of 1–′2 is longer than that from 1′ to 2 of 1′–2. The average ratios of the intervals are:

	1′–2	1–2′
	1′ to 2 : 2 to 1′	1 to 2′ : 2′ to 1
M. M.	1.00 : 0.93	0.90 : 1.00
J. K.	1.00 : 0.91	0.90 : 1.00

This result agrees with that of the beating on the noiseless key, and can be accounted for by attributing it to the same cause. Since the

TABLE X.

Drum beats.

Scheme : 1–2′.

Subject.	Average time from 1 to 2′.	Average time from 2′ to 1.	Number of measurements.	Ratio 1 to 2′ : 2′ to 1.
C. W.	510	550	10	0.93 : 1.00
	499	543	10	0.91 : 1.00
	541	574	10	0.94 : 1.00
	534	561	10	0.95 : 1.00
	550	599	10	0.92 : 1.00
	559	591	10	0.95 : 1.00
	576	618	10	0.93 : 1.00
	567	611	10	0.93 : 1.00
	470	538	10	0.87 : 1.00
	489	523	10	0.91 : 1.00
J. K.	618	640	10	0.96 : 1.00
	652	658	10	0.99 : 1.00
	661	680	10	0.97 : 1.00
	680	685	10	0.99 : 1.00
	676	685	10	0.98 : 1.00
	657	698	10	0.94 : 1.00
	727	735	8	0.99 : 1.00
	693	718	10	0.96 : 1.00
	635	761	9	0.83 : 1.00
	678	683	10	0.99 : 1.00
M. M.	572	636	10	0.89 : 1.00
	672	756	10	0.89 : 1.00
	632	654	10	0.96 : 1.00
	629	691	10	0.91 : 1.00
	633	667	10	0.94 : 1.00
	583	641	10	0.91 : 1.00
	627	693	10	0.90 : 1.00
	579	628	10	0.92 : 1.00
	572	632	10	0.92 : 1.00
	575	622	10	0.92 : 1.00

Unit of measurement, $\sigma = 0.001^s$.

time 2′ to 1 of the scheme 1–2′ is an interval which comes between the rhythmic group, it is made longer by the "pause" in addition to the influence of the emphasis.

Table XI shows the results of the experiments on the scheme 1′–2–3. The proportion is obtained by regarding 1′ to 2 as a unit.

It will be observed in the table that the time 1′ to 2, which follows the emphasis is in general longer than 2 to 3 and 3 to 1′. The time 1′ to 2 is constantly longer than 2 to 3, but in some cases it is shorter than 3 to 1′, owing to the lengthening of the latter by the "pause."

The results of the experiment on the scheme 1–2′–3 are given in the Table XII. The time 2′ to 3 is longer than 1 to 2′ with exception of a few cases. The time 2′ to 3 is in general shorter than 3 to 1. This fact indicates that there is a strong tendency to lengthen the time be-

TABLE XI.

Drum beats.

Scheme: 1′–2–3.

Subjects.	Average time from 1′ to 2.	Average time from 2 to 3.	Average time from 3 to 1′.	Number of measurements.	Ratios 1′ to 2:2 to 3:3 to 1′.
C. W.	611	604	597	10	1.00 : 0.99 : 0.97
	604	599	593	10	1.00 : 0.99 : 0.98
	582	592	588	10	1.00 · 1.02 : 1.01
	655	644	620	10	1.00 : 0.98 : 0.94
	628	618	618	10	1.00 : 0.98 : 0.98
	613	610	601	10	1.00 : 0.99 : 0.98
	669	647	646	10	1.00 : 0.96 : 0.96
	671	667	654	10	1.00 : 0.93 : 0.82
	674	668	650	10	1.00 : 0.99 : 0 96
	676	626	642	10	1.00 : 0.93 : 0.95
	656	643	629	9	1.00 : 0.98 : 0.95
	640	643	626	10	1.00 : 1.00 : 0.97
J. K.	414	392	400	10	1.00 : 0.94 : 0.97
	410	414	416	10	1.00 : 1.01 : 1.01
	432	406	404	10	1.00 : 0.94 : 0.94
	402	381	379	7	1.00 : 0.95 : 0.94
	438	419	421	10	1.00 : 0.95 : 0.96
	437	409	421	10	1.00 : 0.93 : 0.96
	439	415	427	10	1.00 : 0.94 : 0.97
	435	420	422	10	1.00 : 0.96 : 0.97
	428	415	427	10	1.00 : 0.97 : 0.99
	689	691	678	10	1.00 : 1.00 : 0.98
	685	677	670	10	1.00 : 0.98 : 0.97
M. M.	993	603	1063	8	1.00 : 0.63 : 1.07
	959	569	1029	9	1.00 : 0.59 : 1.07
	1108	588	1034	9	1.00 : 0.53 : 0.93
	811	775	789	7	1.00 : 0.95 : 0.93
	783	760	805	10	1.00 : 0.97 : 1.02
	795	776	807	10	1.00 : 1.97 : 1.01
	703	696	728	10	1.00 : 0.99 : 1.04
	748	694	737	10	1.00 : 0.93 : 0.98
	894	596	871	9	1.00 : 0.66 : 0 87

Unit of measurement, $\sigma = 0.001^s$.

tween the rhythmic groups. The same tendency is more marked here in 1–2′–3 than in 1′–2–3.

The above observations will indicate how closely the results of the drum beats coincide with those of the beating on the noiseless key, notwithstanding the difference of the conditions in the two experiments, the one being a finger movement without sound, the other an arm movement with sound.

From the above two series of experiments the following general conclusions can be drawn:

1. The interval which follows an emphasized beat is lengthened.
2. The interval which comes between rhythmic groups is lengthened.

3. The lengthening of the interval between rhythmic groups is not equally great in all the rhythmic schemes.

TABLE XII.

Drum beats.

Scheme: 1–2′–3.

Subject.	Average time from 1 to 2′.	Average time from 2′ to 3.	Average time from 3 to 1.	Number of measurements.	Ratios 1 to 2′:2′ to 3:3 to 1.
C. W.	551	549	540	10	1.00 : 1.00 : 0.99
	537	543	539	10	0.98 : 1.00 : 0.99
	534	530	540	10	1.01 : 1.00 : 1.02
	506	530	530	10	0.95 : 1.00 : 1.00
	574	597	598	10	0.96 : 1.00 : 0.98
	564	564	578	10	1.00 : 1.00 : 1.02
	556	542	563	10	0.97 : 1.00 : 1.01
	560	554	540	9	1.01 : 1.00 : 0.97
J. K.	444	453	463	10	0.97 : 1.00 : 1.02
	437	437	454	10	1.00 : 1.00 : 1.04
	433	435	435	10	0.99 : 1.00 : 1.00
	451	442	453	10	1.02 : 1.00 : 1.02
	406	425	437	10	0.95 : 1.00 : 1.03
	396	413	433	10	0.95 : 1.00 : 1.05
	411	422	439	10	0.97 : 1.00 : 1.04
	418	423	473	10	0.98 : 1.00 : 1.11
	460	475	472	10	0.97 : 1.00 : 0.99
	431	442	455	10	0.97 : 1.00 : 1.03
M. M.	790	867	899	7	0.91 : 1.00 : 1.04
	798	866	856	9	0.92 : 1.00 : 0.98
	823	908	928	9	0.96 : 1.00 : 1.02
	837	930	946	9	0.87 : 1.00 : 1.02
	809	886	894	10	0.91 : 1.00 : 1.01
	837	952	960	9	0.88 : 1.00 : 1.01
	881	945	975	10	0.93 : 1.00 : 1.03
	914	973	996	9	0.94 : 1.00 : 1.02
	890	970	983	10	0.91 : 1.00 : 1.01

Unit of measurement, $\sigma = 0.001^s$.

IV. Intensity and time in rhythm of speech.

We have already seen that emphasis tends to lengthen the interval in the rhythmic movements of finger and arm. Does the same thing hold true in the rhythm of speech?

In the rhythm of speech we must consider two things: (1) the relation of intensity to the time from the beginning of one syllable to the beginning of the next, and (2) the relation of intensity to the time actually occupied by the sound of the syllable.

GUEST[1] recognized the fact that there is a close relation between the accent and the length of a syllable. He says: "Besides the increase of

[1] GUEST, A History of English Rhythm, I 77, London 1838.

loudness, and the sharper tone which distinguish the accented syllable, there is also a tendency to dwell upon, or in other words, to lengthen its quantity. We cannot increase the loudness or the sharpness of a tone without a certain degree of muscular action, and to put the muscles in motion requires time."

BRÜCKE[1] recorded, with a marker on a smoked drum, the movements of a finger in beating time while he recited verses in iambic hexameter, alcaic and sapphic, in a scanning manner. It was found that the distances of the successive beats were equal.

KRÁL and MAREŠ[2] used the frog muscle preparation for recording the spoken sounds in Bohemian verse. A telephone was connected by wires to the motor nerve of the muscle, so that the vibrations of the diaphragm of the former interrupting the current would cause the muscle to contract. A pointer attached to the muscle registered the curves on a smoked drum. The results indicated that even with the same person the same vowel has a different length according as the emphasis is greater or less when a verse is recited in a scanning fashion; and that neither in intensity-verse nor time-verse are the lengths of feet ever exactly equal, the ratio of the emphasized half to the unemphasized half of a foot not keeping a relation like 1 : 1, but rather like 30 : 31, or 32 : 33.

In HURST and MCKAY'S[3] experiments on the time relation of poetical meters the subject recited poems representing each of the four usual meters, iambus, trochee, dactyl and anapest, while he beat in unison with the finger on a pointer which registered the length of the beats on a smoked drum. Experiments were also made on "pure" meters without words being thought or said. It was found that "an iambus consists of a short syllable followed by a long; a trochee of a long followed by a short, a dactyl of a long followed by two short syllables, and an anapest of two shorts followed by a long, yet with no fixed proportions between the syllables." In iambic meter the syllables have a ratio of about 1 : 2 and in the trochaic of 1 to a little less than 1.5 In anapestic meter the ratios were about 1 : 1 : 1.2 and in dactylic 1.6 : 1.1 : 1. In these experiments the investigators did not take any records of the spoken sounds, but only of the rhythmic strokes of the hand. The periods of the strokes of hand, however, are not identical with the lengths of the syllables.

[1] BRUCKE, Die physiologischen Grundlagen der neuhochdeutschen Verskunst, 23, Wien 1871.

[2] KRÁL A MAREŠ, *Trvání hlásek a slabik dle objektivné míry*, Listy Filologické, 1893 IV 17.

[3] HURST AND MCKAY, *Experiments on the time relation of poetical meters*, Univ. of Toronto Stud., Psychol. Series, No. 3, 1899.

In the following experiments I have made an attempt to study the problem by taking records of spoken sounds.

For recording the speech vibrations an electric voice key[1] of a special form[2] was used (Fig. 5). The cylinder of hard rubber, 5^{cm} in length and

FIG. 5.

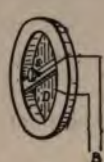

FIG. 6.

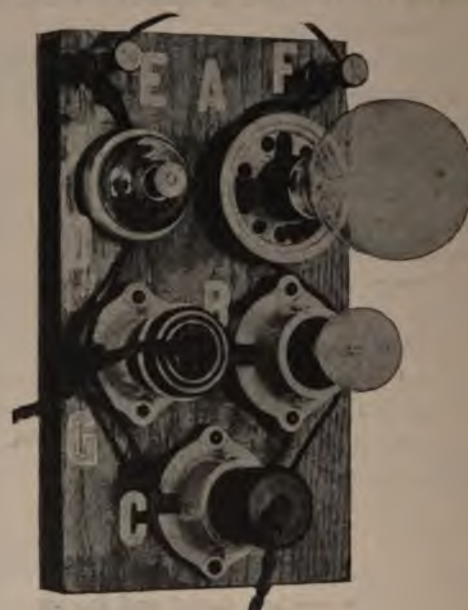

FIG. 7.

3^{cm} in diameter, is closed at one end by a thin sheet of platinum (*D* Fig. 6), while the other end is attached to mouthpiece. A

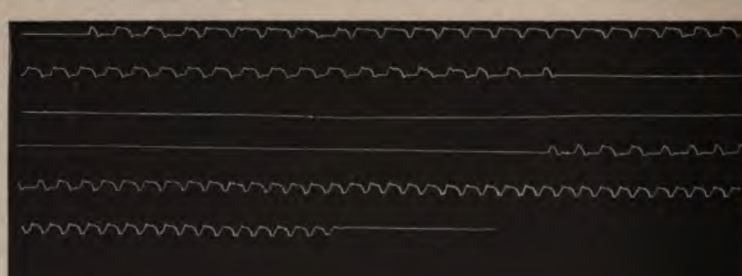

FIG. 8.

[1] CATTELL, *Psychometrische Untersuchungen*, Philos. Stud., 1886 III 313.
[2] SCRIPTURE, *Some new apparatus*, Stud. Yale Psych. Lab., 1895 III 107.

screw (S) with a platinum point is supported by a small metal rod; the point can be placed near the center of the sheet of platinum, so that the latter in its vibration will come in contact with the former and close an electric circuit.

The voice key was connected to one of the sockets of a four-socket lamp battery and the DEPREZ marker to the other, so arranged that the former made a high tension shunt around the latter.[1] The battery arrangement is indicated in Fig. 7; A indicates the intensity lamp, B the tension lamp, C the socket to which the key is connected, and G the socket to which the marker is connected the magnet. The marker recorded the results on the smoked surface of a drum which was run by a storage battery. The current of the battery being very constant the drum revolved at a uniform speed. The time line was drawn by the 100 v. d. fork.

With this method the cord vibrations in vowels can be recorded. A specimen record is given in Fig. 8; the time-line is at the bottom.

TABLE XIII.

Rhythm of speech.

Scheme: 1′–2.

Subject.	Average time from 1′ to 2.	Average time from 2 to 1′.	Number of measurements.	Ratio 1′ to 2 : 2 to 1′.
E	682	661	10	1.00 : 0.98
	689	690	10	1.00 : 1.00
	615	603	10	1.00 : 0.94
	696	673	10	1.00 : 0.94
K	658	663	10	1.00 : 1.01
	599	596	10	1.00 : 1.00
	943	935	10	1.00 : 0.97
B	765	743	10	1.00 : 0.97
	733	714	10	1.00 : 0.97

Unit of measurement, $\sigma = 0.001^s$.

TABLE XIV.

Rhythm of speech.

Scheme: 1–2′.

Subject.	Average time from 1 to 2′.	Average time from 2′ to 1.	Number of measurements.	Ratio 1 to 2′ : 2′ to 1.
E	691	846	10	0.81 : 1.00
	664	913	10	0.71 : 1.00
K	575	649	9	0.90 : 1.00
	563	936	10	0.89 : 1.00
B	575	774	10	0.74 : 1.00
	618	714	10	0.86 : 1.00

Unit of measurement, $\sigma = 0.001^s$.

[1] SCRIPTURE, *New apparatus and methods*, Stud. Yale Psych. Lab., 1896 IV 79.

Table XV.

Rhythm of speech.

Scheme: 1′–2–3.

Subject.	Average time from 1′ to 2.	Average time from 2 to 3.	Average time from 3 to 1′.	Number of measurements.	Ratios 1′ to 2 : 2 to 3 : 3 to 1′.
E	669	605	617	10	1.00 : 0.90 : 0.92
	630	594	613	10	1.00 : 0.94 : 0.97
K	709	615	606	10	1.00 : 0.86 : 0.85
	664	609	610	10	1.00 : 0.91 : 0.92

Unit of measurement, $\sigma = 0.001^s$.

Table XVI.

Rhythm of speech.

Scheme: 1–2′–3.

Subject.	Average time from 1 to 2′.	Average time from 2′ to 3.	Average time from 3 to 1.	Number of measurements.	Ratios 1 to 2′ : 2′ to 3 : 3 to 1.
E	590	600	614	10	0.98 : 1.00 : 1.02
	616	622	633	10	0.97 : 1.00 : 1.02
K	713	751	775	10	0.95 : 1.00 : 1.03
	697	722	786	10	0.96 : 1.00 : 1.09
	717	751	759	10	0.95 : 1.00 : 1.01

Unit of measurement, $\sigma = 0.001^s$.

Table XVII.

Rhythm of speech.

Scheme: 1′–2.

Subject.	Average length of a_1'.	Average length of a_2.	Number of measurements.	Ratio $a' : a$.
E	368	317	10	1.00 : 0.86
	392	355	10	1.00 : 0.93
	445	389	10	1.00 : 0.87
	417	355	10	1.00 : 0.83
K	325	311	10	1.00 : 0.96
	355	306	10	1.00 : 0.86
	787	373	10	1.00 : 0.96
B	451	273	10	1.00 : 0.61
	448	307	10	1.00 : 0.68

Unit of measurement, $\sigma = 0.001^s$.

During the experiments the subject was put in the silent room as in the preceding experiments. He held the voice key in his left hand and recited a series of *a* sounds (like *a* in *father*) in a scanning manner, changing the loudness according to different rhythmic schemes.

Tables XIII to XVI give the results of the measurements of the lengths of the intervals. For the interval, the distance between the be-

TABLE XVIII.

Rhythm of speech.

Scheme: 1–2′.

Subject.	Average length of a_1.	Average length of a_2'.	Number of measurements.	Ratio $a:a'$.
E	339	368	10	0.92 : 1.00
	322	381	10	0.87 : 1.00
K	294	345	10	0.85 : 1.00
	316	356	10	0.90 : 1.00
B	275	395	9	0.69 : 1.00
	322	400	10	0.80 : 1.00

Unit of measurement, $\sigma = 0.001^s$.

TABLE XIX.

Rhythm of speech.

Scheme: 1′–2–3.

Subject.	Average length of a_1'.	Average length of a_2.	Average length of a_3.	Number of measurements.	Ratios $a':a:a$.
E	342	280	277	10	1.00 : 0.82 : 0.81
	330	288	256	10	1.00 : 0.87 : 0.77
K	312	240	195	10	1.00 : 0.76 : 0.63
	322	294	242	10	1.00 : 0.89 : 0.78

Unit of measurement, $\sigma = 0.001^s$.

TABLE XX.

Rhythm of speech.

Scheme: 1–2′–3.

Subject.	Average length of a_1.	Average length of a_2'.	Average length of a_3.	Number of measurements.	Ratios $a:a':a$.
E	308	371	283	10	0.83 : 1.00 : 0.79
	351	365	329	10	0.99 : 1.00 : 0.93
K	377	410	378	10	0.92 : 1.00 : 0.92
	396	439	406	10	0.90 : 1.00 : 0.92
	353	382	348	10	0.92 : 1.00 : 0.91

Unit of measurement, $\sigma = 0.001^s$.

ginning of a sound and the beginning of the next sound was measured. The unit of measurement was $\sigma = 0.001^s$. The ratios are found by regarding the interval which follows the emphasized beat as the unit in all the four different rhythmic schemes.

It will be seen from the tables that the results are substantially the same as those of the foregoing experiments in tapping with the finger and in

the drum beats: (1) the interval which follows the accented syllable is lengthened; (2) the interval between the rhythmic groups is lengthened.

In the scheme 1–2′, the time from 2 to 1′ is constantly longer than 1 to 2′, but in 1′–2, 1′ to 2 is in some cases shorter than 2 to 1′. This is due to the same fact noted before, that the interval between the rhythmic groups includes a pause. The same phenomenon is more marked in the scheme 1–2′–3 than in 1′–2–3.

Tables XVII, XVIII, XIX, XX give the lengths of the accented and unaccented syllables. In the ratios the average length of the accented syllable is always regarded as the unit. The unit of measurement of the average length is $^{\sigma} = 0.001^{s}$.

The following facts can be seen in the tables: (1) the accented syllable is always longer than the unaccented syllable; (2) the last syllable of a rhythmic group is not lengthened unless it is accented. In this respect the length of a syllable differs from the length of an interval.

V. Intensity and pitch in rhythm of speech.

According to Mitford,[1] the strengthened syllables in English have an acuter tone or a higher note. The fact can be abundantly proved, he supposed, if we find or coin a word which is composed of syllables without variety of vowel sound and pronounce it with a strong accent on either syllable.

Müller[2] noticed that in a larynx separated from the body the pitch of the tone might be raised by an increase of the force of blast. He thought that one of the modes of producing high notes without increasing the tension of the vocal ligament is to blow with greater force, by which means the notes may without difficulty be raised through a series of semi-tones to the extent of a "fifth."

I found it possible to make some observations concerning the relation between intensity and pitch in the records which were taken in the preceding experiments. It must be remembered that the subjects of the experiments were requested to recite, in a scanning manner, a series of *a* sounds, changing the intensity according to the prescribed rhythmic scheme, no instruction being given as to the pitch of the tone.

The wave lines in the records corresponded to the periods of the cord vibrations (see Fig. 8). The first step in the study of the pitch in the

[1] Mitford, Inquiry into the Principle of Harmony in Language and of the Mechanism of Verse, Modern and Ancient, 57, London 1804.

[2] Müller, The Physiology of the Senses, Voice and Muscular Motion, with the Mental Faculty, trans. by Baily, London 1848.

records was to measure the actual lengths of the waves in succession. This gave the lengths of the successive periods in the cord vibrations.

The following are the results of the measurements. The unit for the lengths of the periods is $^\sigma = 0.001^s$.

A. Rhythmic scheme: 1′–2.

Subject K.

Example 1. The successive periods of *a′* were: 7, 7, 7, 7, 7, 6, 6, 6, 6, 6, 6, 6, 6, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4^σ. The successive periods of *a* were: 8, 8, 8, 8 8, 8, 8, 8, 8, 8, 8, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, 7^σ. Or more briefly, *a′*: 7^σ (5 times), 6^σ (8 times), 5^σ (16 times), 4^σ (38 times); *a*: 8^σ (11 times), 7^σ (32 times).

The changes in the lengths of the periods were not sudden but very gradual in this record as well as in all other records. The accented syllable began with a period of 7^σ and changed gradually through 6^σ and 5^σ to 4^σ, which was reached at the 30th vibration and maintained to the end. In other words the pitch changed upward from 143 complete vibrations per second, through 170 and 200 to 250 per second.

The unaccented syllable, on the other hand, began with a period of 8^σ, and reached 7^σ at the 12th vibration, which was kept to the end. That is, the pitch changed from 125 upward to 143 complete vibrations a second.

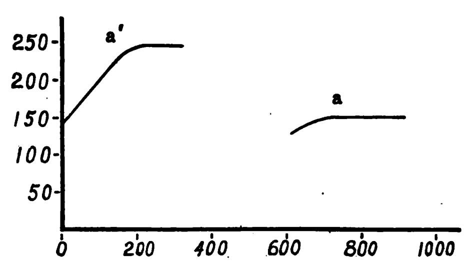

FIG. 9.

The results are shown in Fig. 9. In this, as well as in the other similar figures, the horizontal axis indicates time, while the vertical ordinate gives the number of cord vibrations a second. The space between the curves corresponds to the empty interval between the syllables.

Example 2. The *a′* had 22 vibrations, occupying the successive periods as follows: 8^σ (7 times), 7^σ (5 times), 6^σ (4 times), 5^σ (4 times).

The *a* consisted of 38 vibrations and the successive periods run: 9^{σ} (12 times), 8^{σ} (6 times), 7^{σ} (20 times).

The accented syllable began with 125 vibrations a second and changed upward through 143 and 167 to 200 vibrations a second. About three-fourths of the whole length were occupied by 200 vibrations a second,

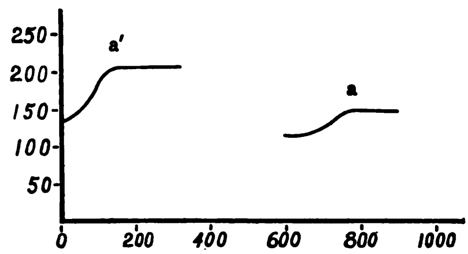

FIG. 10.

which extended from the 17th vibration to the end. The unaccented *a* began with 111 vibrations a second and changed through 125 to 143. The results are shown in Fig. 10.

Subject E.

Example 1. The successive periods of *a'* were: 7^{σ} (12 times), 6^{σ} (17 times), 5^{σ} (52 times); those of *a* were: 7^{σ} (43 times), 6^{σ} (21 times).

The pitch of the accented sound glided upward from 143 vibrations a second through 176, reaching 200 at the 30th vibration, which was kept to the end. The unaccented sound began with 143 vibrations a second and changed through 176. It must be noticed here that although

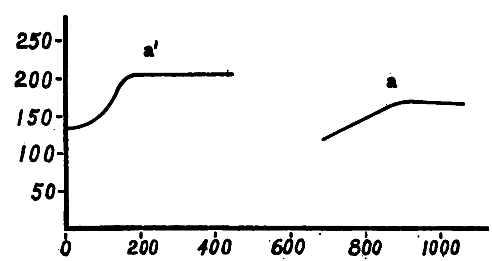

FIG. 11.

a' as well as *a* began with the same pitch, 143 vibrations a second, the former reached 167 at the 13th vibration, while the latter reached the same pitch not before the 44th vibration. The greater part of *a* was occupied by 120 vibrations per second, while about the two-thirds of *a'* were occupied by 143. The results are shown in Fig. 11.

Example 2. The successive periods of a' were: 7^{σ} (5 times), 6^{σ} (15 times), 5^{σ} (50 times); and those of a: 7^{σ} (18 times), 6^{σ} (39 times).

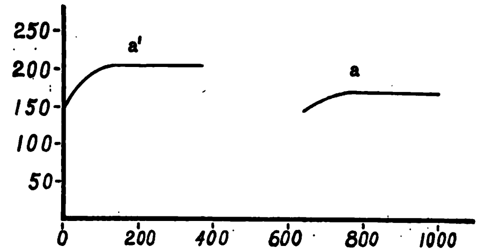

FIG. 12.

The pitch of a' beginning with 143 vibrations a second rose through 167 to 200; a began with 143 and changed slowly to 174. The results are shown in Fig. 12.

Subject B.

Example 1. The successive periods of a' were: 8^{σ} (14 times), 7^{σ} (58 times); those of a: 10^{σ} (40 times).

The pitch of a' began with 125 vibrations a second and rose gradually, reaching 143 at the 15th vibration. The pitch of a was constant at 100 vibrations a second. The results are given in Fig. 13.

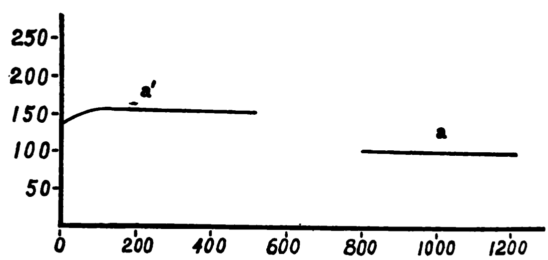

FIG. 13.

Example 2. The total number of vibrations of a' was 67, the successive periods occupying: 8^{σ} (25 times), 7^{σ} (42 times). The a had 26

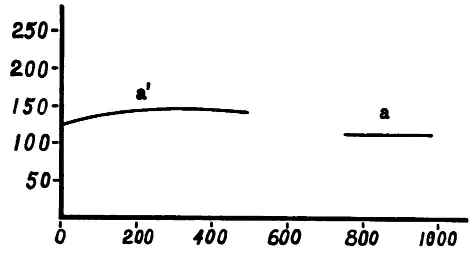

FIG. 14.

vibrations of a constant period of 9^σ. The pitch of *a'* changed from 125 vibrations a second upward to 167, while that of *a* was uniform at 111, as indicated in Fig. 14.

B. Rhythmic scheme: 1–2'.

Subject K.

Example 1. The successive periods of *a* were: 9^σ (19 times), 8^σ (22 times); those of *a'* were: 8^σ (7 times), 7^σ (4 times), 6^σ (5 times), 5^σ (56 times).

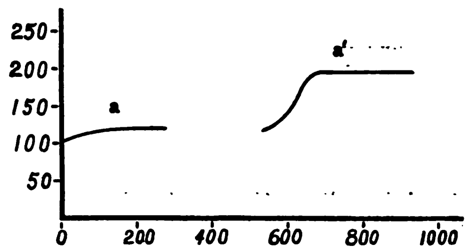

FIG. 15.

The pitch of *a* beginning with 111 gradually rose to 125 vibrations a second; *a'* began with 125 vibrations a second and glided upward through 143 and 167 to 250, as indicated in Fig. 15.

Example 2. The successive periods of *a* were: 9^σ (8 times), 8^σ (32 times); of *a'*: 8^σ (9 times), 7^σ (4 times), 6^σ (9 times), 5^σ (46 times). The pitch of the emphasized *a* changed from 111 vibrations a second

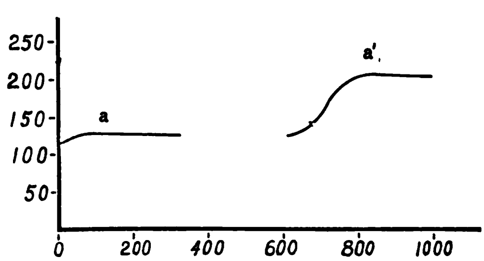

FIG. 16.

to 125, while that of the unemphasized *a* began with 125 vibrations a second and underwent gradual change through 143 and 167 to 200, as indicated in Fig. 16.

The change of the rhythmic scheme does not affect the pitch. The accented syllable has a higher pitch than the unaccented syllable as before.

Subject B.

Example 1. The successive periods of *a* were: 10^σ (30 times); those of *a'*: 7^σ (53 times), 6^σ (4 times). The pitch of *a* was constant

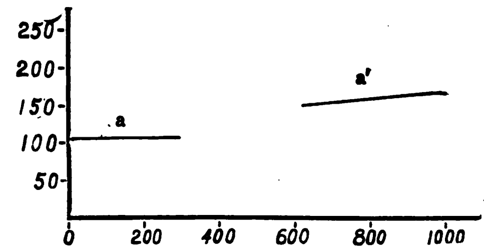

FIG. 17.

at 100 vibrations a second; the pitch of *a'* on the contrary began with 143 vibrations a second and rose toward the end to 167, as indicated in Fig. 17.

Example 2. The successive periods of *a* were: 9^σ (32 times), those of *a'*: 8^σ (3 times), 7^σ (51 times). The pitch of the unaccented vowel

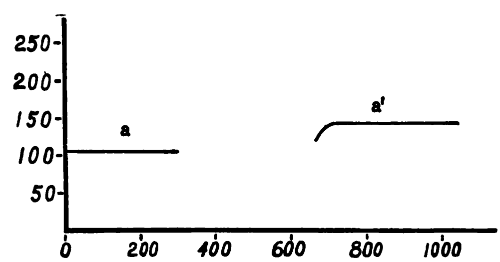

FIG. 18.

was again lower and more uniform than that of the accented. The latter beginning with 125 vibrations a second reached 143 at the 4th vibration, which was kept to the end as indicated in Fig. 18.

C. Rhythmic scheme: 1'–2–3.

Subject K.

Example 1. The successive periods of *a'* were: 7^σ (4 times), 6^σ (5 times), 5^σ (8 times), 4^σ (42 times); the middle *a* occupied the successive periods: 9^σ (3 times), 8^σ (29 times); the last *a*: 9^σ (25 times). The pitch of the accented syllable beginning with 143 vibrations a second rose upward through 167 and 200, reaching 250 at the 18th vibration. The pitch of the first unaccented *a* began with 111 vibrations a second

and rose after three vibrations to 125, which was maintained to the end. The second unaccented *a* was constant at 111 vibrations a second. The results are indicated in Fig. 19.

Example 2. The successive periods of *a'* were: 7^{σ} (10 times), 6^{σ} (11 times), 5^{σ} (7 times), 4^{σ} (32 times); the middle *a*: 9^{σ} (9 times), 8^{σ}

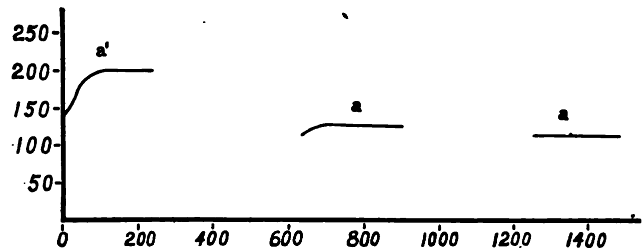

FIG. 19.

(23 times); and those of the last *a*: 8^{σ} (31 times). The mode of change of pitch is substantially the same as the preceding example. The accented syllable beginning with 143 vibrations a second rose through 167 and 200 to 250, which was reached at the 28th vibration.

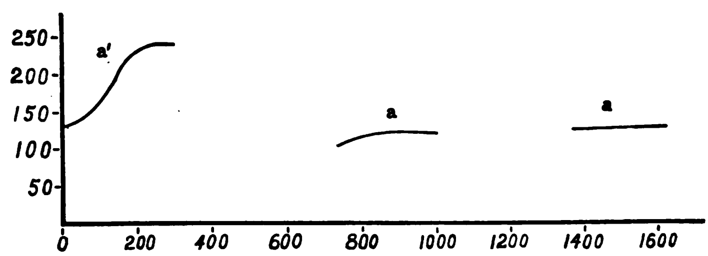

FIG. 20.

The first unaccented syllable began with 111 vibrations a second and changed to 125. The second unaccented syllable was constant at 125 vibrations a second and is uniform. The results are indicated in Fig. 20.

Subject E.

Example 1. The successive periods of *a'* were: 6^{σ} (22 times), 5^{σ} (37 times); those of the middle *a*: 8^{σ} (37 times), and those of the last *a*: 8^{σ}(24 times), 9^{σ} (4 times), 10^{σ} (4 times). The pitch of the accented syllable beginning with 167 vibrations a second rose to 200. The first unaccented syllable was constant at 125 vibrations a second. The pitch of the second unaccented syllable began with 125 vibrations a second

and glided downward through 111 to 100. The results are indicated in Fig. 21.

Example 2. The successive periods of a' were: 7^σ (11 times), 6^σ (8 times), 5^σ (41 times); those of the middle a: 8^σ (40 times); and those

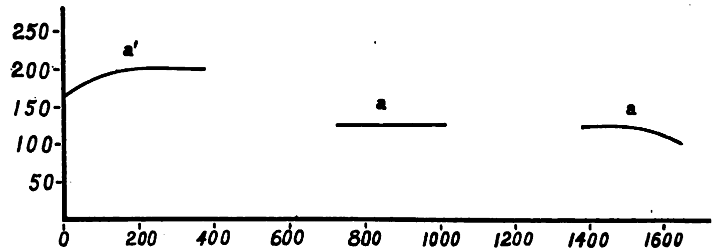

Fig. 21.

of the last a: 8^σ (23 times), 9^σ (4 times), 10^σ (9 times). The pitch of a' begins with 143 vibrations a second and rose through 167 to 200 which, being reached at the 20th vibration, was kept to the end. The pitch of the first unaccented a was constant at 125 vibrations a second.

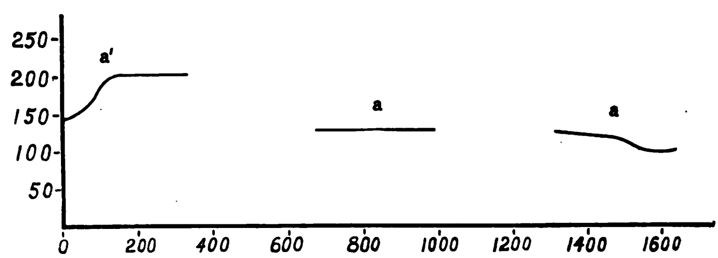

Fig. 22.

That of the second unaccented a began with 125 and glided downward through 111 to 100. The results are indicated in Fig. 22.

We have to observe here that there are some individual differences between the two subjects in regard to the mode of the change of the pitch. With the subject K, the first unaccented syllable is constant, while with E, the second unaccented syllable is constant. With K, the change of pitch is always from lower to higher, but with E the second unaccented syllable in this scheme goes from higher to lower.

D. Rhythmic scheme: 1–2′–3.

Subject K.

Example 1. The successive periods of the first a were: 8^σ (9 times), 7^σ (48 times); those of a': 7 (2 times), 6^σ (6 times), 5^σ (9 times), 4^σ

(86 times); those of the last *a*: 9$^\sigma$ (12 times), 8$^\sigma$ (18 times), 7$^\sigma$ (9 times). The pitch of the first unaccented syllable beginning with 125 vibrations a second changed to 143. The unaccented syllable began with 143 vibrations a second and rose through 167 and 200 up to 250

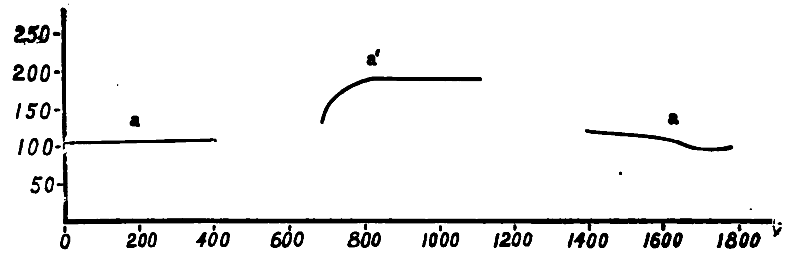

FIG. 23.

at the 18th vibration. That of last *a* began with 111 vibrations a second and glided upward through 125 to 143. The results are shown in Fig. 23.

Example 2. The successive periods of the first *a* were: 9$^\sigma$ (9 times), 8$^\sigma$ (7 times), 7$^\sigma$ (17 times), 6$^\sigma$ (24 times). Those of *a'* were: 8$^\sigma$ (3 times), 7$^\sigma$ (4 times), 6$^\sigma$ (5 times), 5$^\sigma$ (12 times), 4$^\sigma$ (74 times); those of the second *a*: 9$^\sigma$ (9 times), 8$^\sigma$ (6 times), 7$^\sigma$ (11 times), 6$^\sigma$ (33 times). The first unaccented *a* began with 111 and glided upward

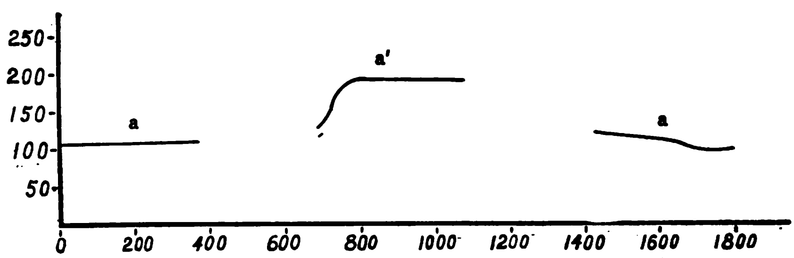

FIG. 24.

through 125 and 143 to 167. The emphasized *a'* beginning with 125 changed upward through 143, 167 and 200 to 250 at the 24th vibration, from which point the pitch was constant. The last *a* began with 111 and changed through 125 and 143 to 167. The results are shown in Fig. 24.

Subject E.

Example 1. The period of the first *a* was constant at 8$^\sigma$ (49 times). The periods of *a'* were: 7$^\sigma$ (2 times), 6$^\sigma$ (13 times), 5$^\sigma$ (66 times); those of the last *a*: 8$^\sigma$ (27 times), 9$^\sigma$ (10 times), 10$^\sigma$ (7 times). The

pitch of first *a* was constant at 125 vibrations a second; the *a'* beginning with 143 vibrations a second changed through 167 to 200, which occu-

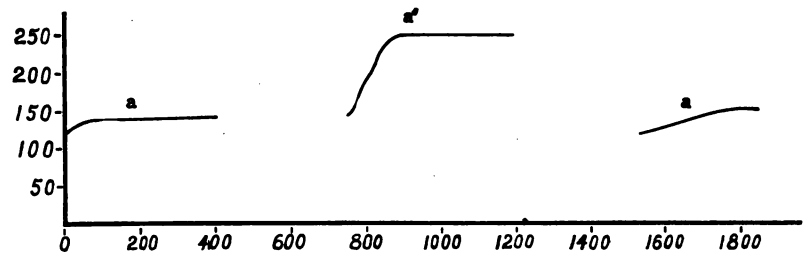

FIG. 25.

pied the most part of the entire length; the last *a* began with 125 vibrations a second and glided downward through 111 to 100 (Fig. 25).

Example 2. The period of the first *a* was constant at 8^σ (46 times). The periods of the *a'* were: 7^σ (5 times), 6^σ (5 times), 5^σ (66 times); those of the last *a*: 8^σ (28 times), 9^σ (6 times), 10^σ (10 times). The pitch of the first *a* was constant at 125 vibrations a second, as in the

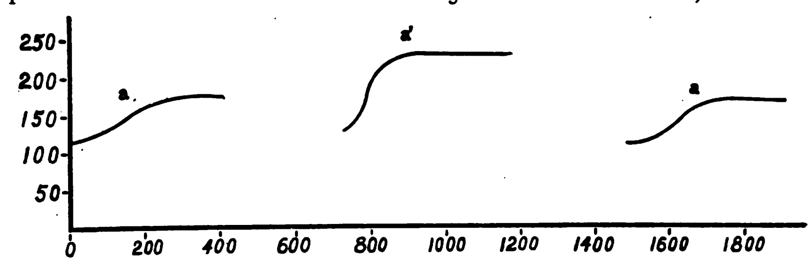

FIG. 26.

last example, that of *a'* beginning with 143 changed upward through 167 to 200. The last *a* beginning with 125 vibrations a second glided downward through 111 to 100 (Fig. 26).

We observe again that there are individual differences between the two subjects in the mode of the change of the pitch. With the subject K the first *a* underwent a change, while with E it was constant; with K, the last *a* glided upward, while with E it glided downward.

E. Conclusions.

From the above observations the following conclusions can be drawn:

1. The accented syllable has a higher pitch than the unaccented syllable.

2. The accented syllable begins in general with a higher pitch than the unaccented syllable.

3. Even in the cases where both accented and unaccented syllables begin with the same pitch, the former glides upward higher than the latter.

4. The pitch of the accented syllable undergoes greater changes than that of the unaccented one.

5. The pitch of the accented syllable always glides upward.

6. The pitch of the unaccented syllable also glides upward in the majority of cases, but sometimes glides downward.

SWEET[1] accounts for the relation between intensity and pitch by attributing it to an emotional attitude of the subject. He thinks "all energetic emotions naturally express themselves in high tones and forceful utterance, and increased vehemence of emotion is accompanied by a rise in force and pitch." This explanation is hardly applicable to our case, because we cannot suppose that in reciting a series of simple sounds, like *a*, a change of emotion would take place that would bring about such a difference between the accented and unaccented syllables.

MITFORD[2] supposed that when we pronounce an accented syllable, we raise the tongue near to the palate, with the consequence of the rise of the height of tone. "To produce the proper English intonation" he says "the tongue must be raised up in pronouncing the strengthened syllable, the vibration will be felt more about the palate and the tone will be acuter, it will be a higher note." The change of the position of tongue in the mouth cavity would only affect the resonance tone and not the cord vibration. It thus gives no explanation of the fact.

It seems that the more probable explanation must be sought in the nature of the action of the larynx. BRÜCKE[3] supposed that in strong accentuation the vocal cords on account of the strong pressure of the air are more stretched and come closer to each other and that, as a consequence of the increase of the tension of the cords, the pitch of the tone is raised. SCRIPTURE[4] thinks that the relation between the rise of pitch of the cord tone and the increase in the force of the puff would naturally result from a gradual tightening of the vocal muscles which is due to associated habits of innervation and not to the physical effect of the air pressure in stretching the cords.

The phenomenon perhaps depends also on the nature of the rhythm of speech itself. The three elements of rhythm: intensity, length and pitch, all have the function of producing the emphasis and, being closely associated in our minds, would naturally tend to occur together. This does not mean of course that a rise in pitch must necessarily occur with an

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[1] SWEET, A Primer of Phonetics, 67, Oxford 1890.

[2] MITFORD, An Inquiry into the Principles of Harmony in Language and of the Mechanism of Verse, Modern and Ancient, 62, London 1804.

[3] BRÜCKE, Die physiologischen Grundlagen der neuhochdeutschen Verskunst, 3, Wien 1871.

[4] SCRIPTURE, *Nature of vowels*, Amer. Journ. Sci., 1901 XI 302.

increase of intensity in the rhythm of speech. The two elements can be separated according to different mental conditions. It can be avoided by voluntary control or as the result of practice. MÜLLER[1] says that "since the human organ of voice possesses the power of increasing the intensity of a note from the faintest 'piano' to 'fortissimo,' without its pitch being altered, there must be some other means of compensating the tendency of the vocal cords to emit a higher note when the force of the current of the air is increased. This means evidently consists in modifying the tension of the vocal cords. When a note is rendered more intense, the vocal cords must be relaxed by remission of the muscular action in proportion as the force of the current of the breath through the glottis is increased. When the note is rendered fainter, the reverse of this must occur."

VI. Beating time in connection with rhythm of speech.

The following experiments were made to determine where the moment of the beat of the finger comes when it beats time in connection with the rhythm of speech.

MEYER,[2] working on the same problem with the purpose of determining the position of the arsis in rhythmic articulation, used for recording the voice a mouth trumpet, ending in a MAREY tambour covered with a fine rubber membrane to which a small straw lever ending in a light pointer was attached. The beat of the finger was made on an apparatus composed of plates of hard rubber connected by a string to a time marker. The subject recited some syllables into the tambour through the trumpet, while he beat time on the rubber plate. Thus the breath curve and the moment of beating could be recorded simultaneously on the smoked drum. In all cases, except where the syllable began with a voiced explosive (*b*, *d*, *g*), the beat came before the vowel. Both the tambour and the beating apparatus, used in the experiment, had considerable latent times which could be only roughly measured to be about 8^σ for the former and 25^σ for the latter. A somewhat more accurate method seemed desirable.

In the following experiments I used the voice key described above on p. 24. As the light diaphragm of platinum vibrated very easily at a short distance from the mouth, it recorded the first vibration of the voice with a latent time of not over half a thousandth of a second. The voice key was put in one of the wire circuits of a lamp battery and a DEPREZ marker in the other, as in the preceding experiments (p. 25). The

[1] MÜLLER, The Physiology of the Senses, Voice and Muscular Motion, with the Mental Faculties, trans. by Baily, 1034, London 1848.

[2] MEYER, *Beiträge zur deutschen Metrik*, Neuere Sprachen, 1898 VI 1,121.

latent time of the marker was less than 1^{σ} as had been previously determined by frequent tests.

For the beating apparatus the noiseless key in the rubber bag (p. 8) was used. The tension of the key was very small and the slightest touch was enough to overcome the resistance for breaking the contract; the time lost in compression of the finger before the key acted was infinitesimal. The key was connected to the primary circuit of a spark coil while the metallic point of the DEPREZ marker was attached to one pole of the secondary circuit. The arrangement for drawing the time line was the usual one of a 100 v. d. fork. The drum was run by a motor with the storage battery; a very constant speed was attained.

The subject held the voice key in his hand and, putting its mouthpiece close to his lips, recited a syllable in a scanning manner, while he beat time on the noiseless key with the finger of his right hand (generally the index finger), the rate of the movement being left to his choice.

The following syllables were used by different subjects: (1) *a*, (2) *'a*, (3) *ma*, (4) *ha*, (5) *pa*, (6) *ăp*, (7) *āp*, (8) *măm*, (9) *mām*. In these the *a* was pronounced like *a* in "*fa*ther." The *'a* was the same as *a*, but with slight glottal catch at the beginning. Both *ă* and *ā* were the same as *a*, but *ă* was shorter than *ā*, as the sign indicates. All the consonants were pronounced as in English words.

The subjects were four: K, E, T and M. Ten records were generally taken at each single experiment. The results of the experiments are given in the Tables XXI to XXIX. In all the tables the positive signs indicate the deviations when the beats of the finger came before the vowel, and the negative ones those when the beats came after the beginning of the vowel. The first column gives the initials of the subjects, the

TABLE XXI.

Finger beat with 'a.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
K.	+ 22	10	9	1	10.2
	+ 8	10	6	4	13.5
	+ 40	10	10	0	23.0
	+ 10	10	7	3	13.0
	+ 21	10	8	1	13.4
	+ 11	10	8	2	14.6
T.	+ 61	10	9	1	32.5
	+ 80	10	10	0	34.5
	+ 108	10	10	0	38.6
	+ 38	10	10	0	20.7
	+ 75	10	10	0	27.0
	+ 68	10	10	0	20.1

Unit of measurement, $\sigma = 0.001^{s}$.

second the average deviation of the beats of the finger from the beginning of the vowel. The unit of the measurement is $\sigma = 0.001^s$. The third column gives the number of records from which the average is obtained. The fourth and fifth columns give the number of the cases in which the positive and negative deviations occurred respectively. The probable errors are calculated according to the formula used above (p. 6). A summary of the results of the experiments is given in Tables XXX and XXXI. Table XXX contains the average results of individual subjects for different syllables and Table XXXI the total averages from all the results.

TABLE XXII.

Finger beat with ''a.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
E	+ 109	10	10	0	15 7
	· 139	10	10	0	22.0
	+ 112	10	10	0	23.0
	+ 181	10	10	0	10.2
	+ 121	10	10	0	19.2
M	+ 177	10	10	0	12.7
	+ 147	10	10	0	19.5
	+ 80	10	10	0	22.5
	+ 117	10	10	0	40.6

Unit of measurement, $\sigma = 0.001^s$.

TABLE XXIII.

Finger beat with 'ma.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
K	+ 112	10	10	0	28.0
	+ 60	10	9	1	22.2
	+ 70	10	10	0	12.3
	+ 70	10	10	0	12.0
	+ 74	10	10	0	23.0
	+ 70	10	10	0	14.4
E	+ 140	10	10	0	16.0
	+ 124	10	10	0	13.3
	+ 104	10	10	0	14.9
	+ 123	10	10	0	17.2
	+ 111	10	10	0	11.2
T	+ 245	10	10	0	
	+ 129	10	10	0	39.8
	+ 208	10	10	0	27.6
	+ 83	10	10	0	39.0
	+ 261	10	10	0	36.3
	+ 80	10	10	0	41.1
M	+ 177	10	10	0	8.8
	+ 234	10	10	0	19.5
	+ 118	10	10	0	8.4
	+ 123	10	10	10	33.1

Unit of measurement, $\sigma = 0.001^s$.

TABLE XXIV.

Finger beat with 'ha.'

Subject.	Time of beat before *a*.	Number of measurements.	Num er of +.	Number of —.	Immediate probable e rror.
K.	+ 38	10	10	0	18.4
	+ 27	10	9	1	13.1
	+ 93	10	10	0	13.5
	+ 77	10	10	0	8.8
	+ 50	10	10	0	21.3
	+ 49	10	10	0	20.7
E.	+ 110	10	10	0	12.0
	+ 84	10	10	0	14.7
	+ 87	10	10	0	15.0
	+ 78	10	10	0	25.1
	+ 159	10	10	0	10.2
T.	+ 195	10	10	0	46.8
	+ 134	10	10	0	20.1
	+ 106	10	10	0	24.6
	+ 44	10	8	1	20.7
	+ 111	10	10	0	20.1
	+ 76	10	10	0	19.6
M.	+ 174	10	10	0	15.6
	+ 182	10	10	0	19.7

Unit of measurement, $\sigma = 0.001^s$.

TABLE XXV.

Finger beat with 'pa.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
K	+ 59	10	9	1	26.6
	+ 75	10	10	0	17.9
	+ 108	10	10	0	14.6
	+ 62	10	10	0	16.7
	+ 76	10	10	0	21.0
	+ 83	10	10	0	18.5
E	+ 146	10	10	0	21.3
	+ 85	10	10	0	9.3
	+ 142	10	10	0	21.3
	+ 118	10	10	0	13.6
	+ 119	10	10	0	10.2
T	+ 287	8	8	0	
	+ 207	10	10	0	24.5
	+ 170	8	8	0	61.0
	+ 135	10	10	0	15.4
	+ 152	10	10	0	21.3
	+ 161	10	10	0	45.8
M	+ 209	10	10	0	18.8
	+ 140	10	10	0	14.7
	+ 120	10	10	0	14.7
	+ 157	10	10	0	12.6

Unit of measurement, $\sigma = 0.001^s$

Table XXVI.

Finger beat with 'ăp.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
K	+ 51	10	10	0	11.2
	+ 35	10	10	0	4.7
	+ 43	10	9	1	6.8
	+ 11	10	6	4	10.4
	+ 31	10	10	0	8.1
	+ 11	10	7	3	8.6
E	+ 89	10	10	0	7.9
	+ 126	10	10	0	14.0
	+ 54	10	10	0	9.8
	+ 84	10	10	0	30.1

Unit of measurement, $\sigma = 0.001^s$.

Table XXVII.

Finger beat with 'āp.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
K	+ 13	10	7	3	6.4
	+ 43	10	9	1	11.6
	+ 23	10	8	2	14.2
	+ 4	10	5	5	17.4
	— 3	10	4	6	12.6
	— 19	10	2	8	15.9
E	+ 99	10	10	0	20.1
	+ 94	10	10	0	20.2
	+ 90	10	10	0	22.5

Unit of measurement, $\sigma = 0.001^s$

Table XXVIII.

Finger beat with 'măm.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
K	+ 70	10	10	0	18.6
	+ 81	10	10	0	28.8
	+ 32	10	10	0	13.1
	+ 33	10	8	0	26.5
E	+ 60	10	10	0	10.0
	+ 60	10	10	0	12.3
	+ 53	10	10	0	22.1
	+ 71	10	10	0	13.8

Unit of measurement, $\sigma = 0.001^s$.

TABLE XXIX.

Finger beat with 'mām.'

Subject.	Time of beat before *a*.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
E	+ 66	10	10	0	13.0
	+ 73	10	10	0	12 2
	+ 67	10	10	0	71.
	+ 53	10	10	0	13.9
K	+ 50	10	9	0	24.7
	+ 65	10	10	0	28.8
	+ 51	10	9	1	27.8
	+ 72	10	10	0	24.4

Unit of measurement, $\sigma = 0.001^s$.

TABLE XXX.

Summary of Tables XXI to XXIX, for individuals.

Subject.	*ma*	*pa*	*ha*	*'a*	*a*	*ăp*	*āp*	*măm*	*mām*
K	+ 76	+ 96	+ 56		+ 19	+ 30	+ 10	+ 54	+ 60
E	+ 120	+ 140	+ 103	+ 132		+ 88	+ 94	+ 61	+ 64
T	+ 169	+ 181	+ 133		+ 86				
M	+ 163	+ 157	+ 172	+ 130					

Unit of measurement, $\sigma = 0.001^s$.

TABLE XXXI.

Summary of Tables XXI to XXIX, for sounds.

	Average time of beat before vowel.	Number of measurements.	Number of +.	Number of —.
ma	+ 132	210	209	1
pa	+ 143	206	205	1
ha	+ 118	190	187	2
'a	+ 131	70	90	0
a	+ 52	120	107	12
ăp	+ 59	100	92	8
āp	+ 52	90	65	25
măm	+ 57	80	80	1
mām	+ 62	80	78	1

Unit of measurement, $\sigma = 0.001^s$.

The tables show that the beat of the finger comes before the beginning of the vowel in all the following conditions:

(1) when the vowel is preceded by a consonant and is not followed by any other sound;

(2) when the vowel has the glottal catch at the beginning;
(3) when the vowel is neither preceded nor followed by any sound;
(4) when a short vowel is followed by a consonant;
(5) when a long vowel is followed by a consonant;
(6) when the short vowel is preceded and followed by consonants;
(7) when the long vowel is preceded and followed by consonants.

It will be observed also that the amount of time by which the beat occurs before the beginning of the vowel is not the same in the different combinations in which the vowel stands.

The results for the subjects K and T show that the length of time by which the beat occurs before *a*, when not preceded by a consonant, is considerably shorter than that before the vowel when preceded by a consonant. This fact indicates that the consonant lengthens the time between the beat and the beginning of the vowel.

The amount of time between the beat and the beginning of the vowel differs with the different consonants which precede it. The subjects K, E, T all agree in making this difference greatest in *pa*, the next greatest in *ma*, and least in *ha*.

The amount of time by which the beat is ahead in *'a* is not very different from that in *ma*, *pa* and *ḥa*. It is probably due to the fact that the glottal catch at the beginning of the vowel is of the same nature as a consonant in so far as the complexity of action of the vocal organs is concerned.

The results for *măm* and *mām* seem to indicate, if not in a very conclusive manner, that when a vowel is preceded as well as followed by a consonant, the beat tends to come nearer the beginning of the vowel than when the vowel is preceded by a consonant but not followed by another.

The preceding observations show that the finger beat occurs before the vowel. But where does it come in respect to a consonant which precedes the vowel?

Among the three consonants *m*, *p* and *h* which formed the objects of our experiments in combination with the vowel *a*, the last two (*p* and *h*) could be found in the records. The curve for the consonant in our records did not consist of vibrations like those of the vowel, but of a smooth deviation from the record line due to the air pressure. The lengths of the consonants could thus be measured. The results of the measurements are given in Tables XXXII and XXXIII. The unit of the measurement is $\sigma = 0.001^s$.

A summary is given in Table XXXIV.

Table XXXII.

Finger beat with 'ha.'

Subject.	Average length of h.	Immediate probable error.	Average time of beat before h.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
E	43	5.1	+67	10	10	0	7.5
	34	9.0	+53	10	10	0	12.0
	39	6.1	+34	10	10	0	9.4
K	109	13.1	—67	10	0	10	27.2
	124	15.4	—30	10	1	8	18.9
	148	7.4	—88	10	0	10	33.3
	99	21.0	—64	10	0	10	27.0
	106	21.4	—62	10	0	10	32.4

Unit of measurement, $\sigma = 0.001^s$.

Table XXXIII.

Finger beat with 'pa.'

Subject.	Average length of p.	Immediate probable error.	Average time of beat before p.	Number of measurements.	Number of +.	Number of —.	Immediate probable error.
E	54	7.6	+91	10	10	0	17.6
	40	3.4	+49	10	10	0	10.9
	47	4 7	+87	10	10	0	18.6
	47	5.8	+61	10	10	0	14.5
	53	9.3	+56	10	10	0	15 0
K	56	6.2	+16	10	7	2	15.2
	60	8.1	+ 5	10	7	3	18.9
	57	26.0	+29	10	9	1	19.3
	73	33.3	+ 5	10	5	5	18.2
	51	7.7	+11	10	6	4	7.0
	55	10.6	+25	10	8	2	19.5

Unit of measurement, $\sigma = 0.001^s$.

Table XXXIV.

Finger beat with rhythm of speech.

Subjects.	Average length of p.	Average time of beat before p.	Average length of h.	Average time of beat before h.
E	49	+69	39	+51
K	59	+15	117	—61

Unit of measurement, $\sigma = 0.001^s$.

The following points may be observed in the tables:

1. For the syllable *pa* two subjects agree in beating time before the beginning of the consonants.

2. For the syllable *ha*, with the subject E the beats come constantly before the beginning of the consonant, but with K they come in most

cases after the beginning of the consonant, about midway between the consonant and the vowel which follows it.

From the observations reported in this section, the final conclusion can be drawn that the beat of the finger in connection with the rhythm of speech comes before the vowel and before or in the course of the consonant which precedes the vowel.

The preceding observations would not be complete unless a few words are added about the point of emphasis in rhythmic articulation. We would naturally raise a question as to the relation of the beat of the finger to the point of greatest emphasis.

Our experience seems to show that when we recite a verse while we beat time with our hand, the point of the highest emphasis in the rhythm comes at the same moment with the beat.

Although it is not certain whether the innervations of the movements of hand and vocal organ proceed from their nervous centers at exactly the same moment, still we may suppose that the two movements are so closely associated that the innervations of them take place almost simultaneously. But when we attempt to determine the position of the point of emphasis from the beat of the finger, we find that it cannot be easily done. It does not follow that the movements themselves are executed at the same time from the mere supposition that innervations of the movements of hand and vocal organs take place simultaneously.

MEYER[1] supposed that the movements of hand and vocal organ would take place at the same moment, provided the nerve fibers which transmit the impulses are equal in length. He calculated from the rate of nervous transmission that the impluse reaches hand 1.47 hundredths of a second later than vocal organ. Adding the latent time of apparatus to this lost time of nerve transmission he arrived at the final conclusion that the point of emphasis lies in the course of a voiced consonant or shortly before an explosive.

The difference in the length of the nerve fibers is not the only factor which disturbs the simultaneity of the two movements. KÜLPE's experiments[2] showed that we have difficulty in moving our hands at the same time to react to a single stimulus. If even the two hands—alike in construction and symmetrically arranged—are not moved simultaneously, it must be still more difficult to execute the movements of two disparate organs like hand and vocal organs at the same moment.

Besides these differences there may be several other factors which cause the deviation of the two movements. The difference of the complexity

[1] MEYER, *Birträge zur deutschen Metrik*, Neuere Sprachen, 1898 VI 121.

[2] KÜLPE, *Ueber die Gleichzeitigkeit von Bewegungen*, Philos. Stud., 1891 VI 514.

of the constructions of the two organs, might be one of such factors. The condition of attention during the movements might be another.

Therefore, until all the conditions on which the simultaneity of the two movements depends are known, nothing definite can be said about the relation of point of emphasis to the finger beat.

If we assume, however, that the movements of the hand and vocal organs are executed simultaneously, we can conclude from the foregoing experiments that the point of emphasis in the rhythmic speech comes before the vowel and before or in the course of the consonant which precedes the vowel. In other words, the point of emphasis in rhythmic articulation lies at the *beginning* of the movement of the vocal organs for the production of the sound.

RESEARCHES IN EXPERIMENTAL PHONETICS

(Second Series)

BY

E. W. SCRIPTURE.

These researches are a continuation of the first series, published in these Studies.[1]

I. APPARATUS FOR STUDYING SPEECH RECORDS.

The apparatus for transcribing gramophone records[2] has been so developed that the curves are much larger; those shown in Plates I to XI are reproduced directly by photography without any magnification.

The tracing apparatus in the form used for transcribing the records reproduced in these plates is partly shown in a top view in Fig. 1 and in a side view in Fig. 2. The gramophone plate *E* (Fig. 1) is placed on a metal disc (Fig. 2) which is rotated about once in five hours by miter gears connected to the screw barrel in the tube *C* (Fig. 1). This tube is turned by a spur gear *Y* which is moved by a speed reducing mechanism from an electric motor. As *C* revolves, it turns the screw barrel and the gramophone plate; at the same time the screw barrel moves longitudinally through a nut and pushes the plate to the left. The iron plate *D* forms the base of the apparatus. A steel point near *F* in the lever *J*, held by the adjustable support *H* on the base *I*, runs in the speech groove on the gramophone plate. The lever *J* thus repeats the horizontal vibrations in the speech groove. The movements are transferred to the second lever *Q*, working on a fulcrum *O* supported by *P*, by means of the link and gimbal joints *L*, *N*. The movements of *Q* are registered by a point *R* on a band of smoked paper *S* stretched between two drums, of which one is shown at *T*. The drum *T* is moved by a belt from the pulley *X*. The speed of the gramophone plate and that of the drum are thus always in a constant ratio.

The magnification of the vibrations in the speech groove can be of any degree, provided the mechanical working is sufficiently accurate. The following technical points were learned from long and costly experience.

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[1] SCRIPTURE, *Researches in experimental phonetics (first series)*, 1899 VII 1.

[2] SCRIPTURE, as before, 10.

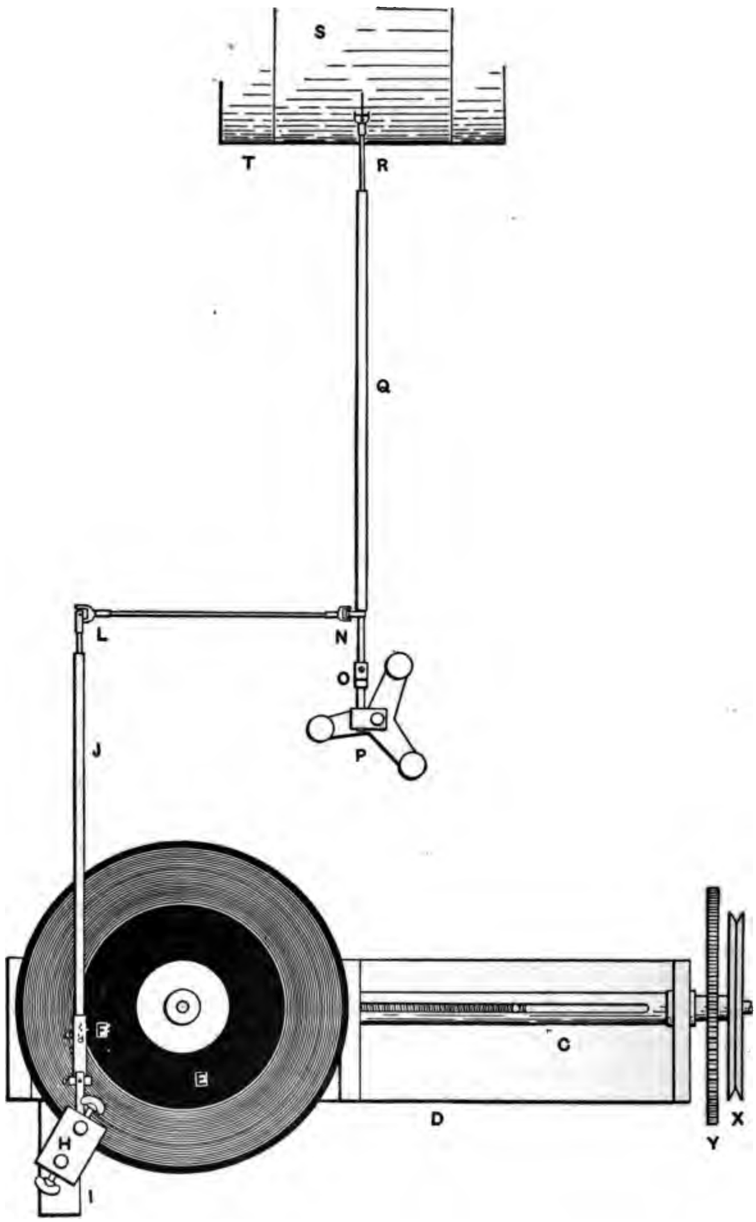

FIG. 1.

The bearings for the levers *J* and *Q* must be perfectly tight and yet perfectly loose; the slightest bind or play destroys the records. To attain this condition all the pivot bearings are made of steel highly polished under a magnifying glass. All parts are made with the utmost lightness and rigidity. The arms *J* and *Q* are of a reed specially imported from Japan; I have been unable to find any other substance that will give equal rigidity with so little weight. The link *LN* is a small reed from Germany used for marking instruments; it has great longitudinal strength, that being all that is required in the application.

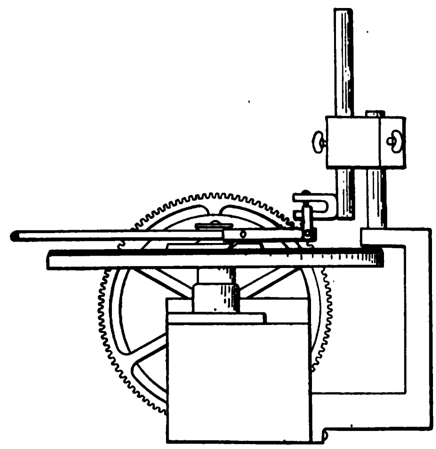

FIG. 2.

The recording point *R* was sometimes of steel in an aluminum holder (as shown in the figure) or was what is known as the BAYLIS recording point. This latter tracing point is worthy of a description. I made my specimens at a suggestion from a medical man; as I have never seen the original account, I cannot tell how widely they may differ. The construction of the point is shown in Fig. 3. A piece of thin card is cut into two portions, and the two are united by the thinnest obtainable rubber membrane (I use some obtained from KŒNIG, of Paris, for manometric flame capsules);

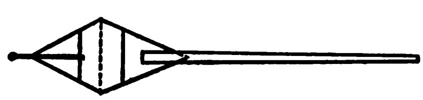

FIG. 3.

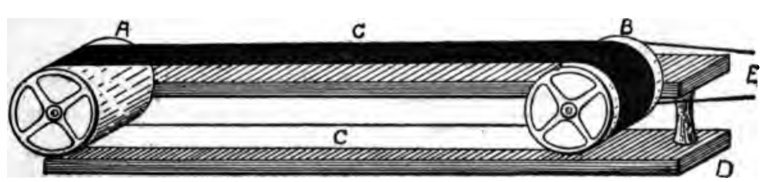

FIG. 4.

this forms an exceedingly delicate hinge. A fine glass thread is made; a piece is broken off; one end is melted to a little ball; and the piece is cemented to the free piece of cardboard. The other piece is attached to

the recording arm. The weight of the free piece keeps the point on the paper; the hinge allows the necessary play.

In order to use long bands of paper the recording drums must be conveniently arranged. One arrangement is shown in Fig. 4. Two plates DE are held together by crossrods. At any points on the edges of these plates metal shafts may be clamped, and two drums A B, with hollow axles, placed on them. A band of paper CC is fastened evenly around the drums and tightened after the paste is dry by adjusting one of

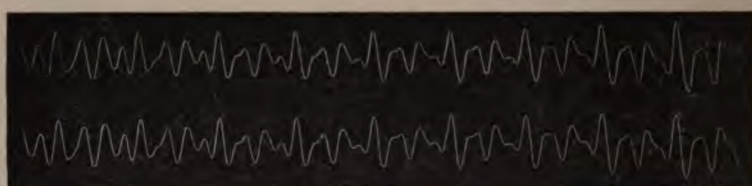

FIG. 5.

the shafts; it is then smoked as usual. To rotate the drums a loose pulley may be placed on one of the shafts before or after the drum is on the support; this pulley has a pin that catches one of the spokes of the drum.

The accuracy with which the machine reproduces the vibrations in the groove on the gramophone plate may be shown by a comparison of repeated tracings of the same curve; the pieces in Fig. 5 were cut from different tracings and were reproduced directly by photography. The tracing is thus done with an accuracy indicated by the likeness of the two records. These differences are so small as to escape anything but microscopic measurement. The fine vibrations in the consonants and some of the vowels, which are lost in the tracing, are smaller than these differences.

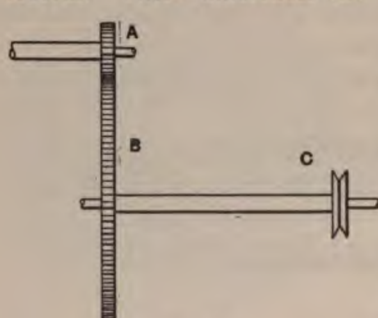

FIG. 6.

As this machine can be run continuously day and night with no supervision except for changing the paper, great quantities of tracings can be accumulated in spite of the low speed.

The problem of reducing the speed of an electric motor to any degree I have solved in the following general way:

An adjustable countershaft fastened to the base of the motor allows the speed to be reduced in transmission. For very high speeds the belt from a pulley on the drum runs directly to a small pulley on the motor axle. For more moderate speeds the countershaft is used with a spur gear *A* on the motor axle and another *B* on the countershaft (Fig. 6); the pulley *C* on the countershaft runs at a lower speed on account of the reduction *AB*. For very low speeds a worm *W* is placed on the motor axle and a worm gear *V* on a spur gear on the countershaft (Fig. 7). When the drum is used with its axis horizontal, a spur gear *S* (Fig. 8) may, if preferred, be placed on its axle and made to connect with a spur gear *T* of any desired size on the countershaft, which is run by a worm *W* on the motor axle. For very low speeds the spur gear *S* (Fig. 9) is run by a worm *X* on the countershaft, which is turned by the worm gear *V* in connection with the worm *W* on the motor axle. A collection of various sizes of pulleys and gears makes it possible to get almost any speed desired; the finer gradations are accomplished by resistances and by slightly pressing or loosening the motor brushes against the commutator.

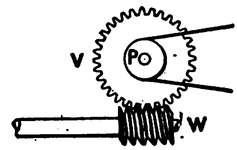

FIG. 7.

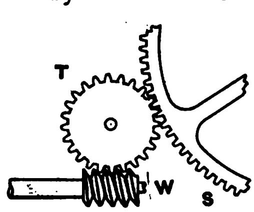

FIG. 8.

For reproducing the tracings the following procedure has been found successful: A narrow strip containing the curve is cut from the smoked paper. This strip is then placed so that it reads from right to left. A piece the length of the desired plate is cut off and pasted on pasteboard. Below this another length is pasted; and so forth until the plate is of the desired height. The edges and open spaces are then blackened. The engraver uses this as copy for making the block, but *omits the process of stripping (or reversing)*. The print from the block thus made will read from left to right. The omission of the stripping avoids the errors due to stretching of the gelatine.

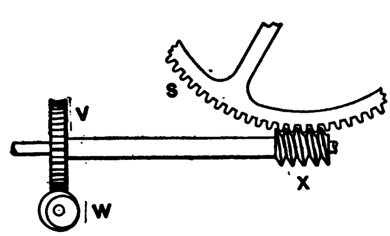

FIG. 9.

II. INTERPRETATION OF SPEECH CURVES.

A curve of speech is at first sight no more intelligible than a line of Chinese ideograms. The knowledge of the speech sounds to which a

certain portion of a curve belongs gives the general meaning of the curve but affords little information concerning its details. A careful study of the sound by the ear reveals some of the grosser characters of the sound, but cannot indicate any of the finer details that lie before the eye in the complexities of the curve. The meaning of these details—the very essentials of the speech sounds—is not apparent at first observation; only by patient and persistent unraveling of the tangled curve is an inkling of it obtained.

The experience of several years has developed a method of studying the tracings from the gramophone (or zonophone) discs that aims to save some of the great amount of time involved.

The words spoken by the gramophone plate are noted on paper with an indication of the relative lengths of the pauses. The pauses are classed as short, medium and long.

The first vibrations on the record are taken as representing the first word on the plate. The first long straight line on the record is taken as the first pause. Then the successive sounds between the beginning and the first pause are assigned to the successive groups of vibrations. This method is followed for succeeding groups of sounds between pauses.

Considerable help is obtained by a familiarity with the peculiarities of speech curves.

A set of speech curves (Plate I) from the *Cock Robin* record will be used to illustrate the first steps taken in analysis. The curve reads from left to right; the italicized letters indicate the sounds recorded.[1] The speech curves in the figure would naturally run along horizontal lines. The slow fluctuations seen in the records are due to irregularities in feeding the gramophone plate sidewise. They in no way affect the accuracy of the records. In making measurements of duration, however, the ruler should always be horizontal.

To interpret the details of a sound the grouping of the vibrations is first noticed. In a series of groups of the same general form each group may usually be considered as arising from one puff of the vocal cords. The minor vibrations arise from the vibrations of the resonating cavities and from the overtones of the cords.

Many of the main features of the speech curves can be obtained by inspection without measurement; very much more can be obtained by simple measurements. Long distances may be measured by millimeter scales; the tenths of a millimeter may be estimated by the eye. Finer measurements may be made with a scale graduated in tenths of a milli-

[1] This account is from SCRIPTURE, *Speech curves, I*, Mod. Lang. Notes, 1901 XVI 71.

meter;[1] the work is done with a watchmaker's eyeglass, or under a magnifying glass. When the curves are very small, the measuring may be done by a microscope with a micrometer object-table or a micrometer eye-piece.[2]

The calculations are all done by books of tables[3] or with a slide rule.[4] The investigator should become familiar with various books containing extensive multiplication tables, tables of reciprocals, etc. A Chinese abacus is also very convenient in adding.

The speech curves are frequently of such a nature that the period of the cord tone may be found by measuring the distance between two like points in two successive groups of vibrations.

The distance in millimeters is translated into time according to the equation valid for the tracing. For all the curves in Plate I except that of "draw your" the relation is $1^{mm}=0.0016^{s}$; for this curve it is $1^{mm}=0.0007^{s}$. Thus, the distance between the two high points in the last vibration in the fourth line is 3.2^{mm}; at 1^{mm} for 0.0016^{s} (use ZIMMERMANN's table for 16) this gives a period of 0.01536^{s} for the cord vibrations at that instant. A period of 0.01536^{s} is the same as a frequency of $1 \div 0.01536$ (use BARLOW for reciprocals) or 65.1.

To illustrate the method a detailed analysis of the words "saw him" will be given in the next section.

III. FURTHER STUDIES OF *Cock Robin*.

The *Cock Robin* record previously described[5] was traced off again with the apparatus shown in Fig. 1. The curves were much larger than the previous ones. Those in Plates I and II are reproduced directly by zinc etching (p. 53) with no enlargement.

[1] For measuring rules: SOCIÉTÉ GENEVOISE, Genève (especially adapted is a 'petite échelle en argentan divisée d'un côté en dixièmes de millimètres' for 20 francs).

[2] For microscopes with micrometer eye-pieces: ZEISS, Jena; BAUSCH & LOMB, Rochester, N. Y. For micrometer object tables: ZIMMERMANN, Leipzig.

[3] For mathematical tables: CRELLE, Rechentafeln, Berlin, 1857 (first English edition, New York, 1888); ZIMMERMANN, Rechentafeln, Berlin, 1891; BARLOW, Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to 10000, reprint edition, London, 1897.

[4] For slide rules and similar calculating instruments: DENNERT & PAPE, Altona; W. F. STANLEY, London; BEYERLEN & CO., Stuttgart; TAVERNIER-GRAVET, Paris; KEUFFEL & ESSER, New York. For adding machines: FELT & TARRANT, New York City. For calculating machines (most advantageous for multiplication and division): BURKHARDT, Glashütte i/S.; BRÜCKNER, Dresden; GRIMME, NATALIS & CIE., Braunschweig. For the curve-adder: CORADI, Zürich.

[5] SCRIPTURE, *Researches in experimental phonetics (first series)*, Stud. Yale Psych. Lab., 1899 VII 14.

The first line on the Plate[1] contains the record of *ɔhim* in *sɔhim* which occurs in the phrase "Who saw him die?" The words are run together in speech on the gramophone, so that there is no pause between *ɔ* and *h*.[2]

The record shows no trace of the *s*. The first vibrations of the curve differ from the rest, and show changing relations between the resonance (or mouth) tone and the cord tone; they indicate that the cords have begun to vibrate while the mouth is still changing from the *s* position to the *ɔ* position. After this the grouping of the vibrations in threes indicates a cord tone with a cavity tone a duodecime higher; this general relation is maintained throughout the vowel. That still other cavity tones are present is indicated by the subordinate modifications of the small vibrations. The sound *ɔ* increases slowly in intensity, but diminishes again as it changes into the following sound. The *i* is quite strong but falls quickly as the sound changes to *m*. The *m* vibrations slowly fade away.

The accompanying table shows the way in which the course of the cord tone in reference to pitch is calculated. It illustrates several important principles used in computing and interpreting results.

The figures in column *A* give the distances in millimeters from apex to apex of the strongest vibrations in the successive groups. The measurements were made by an assistant who did not know the nature of the problem investigated. It is very important to note the following:

1. The determination of the exact point to be called the apex may be indefinite to the extent of one or two tenths of a millimeter, owing (*a*) to the roundness of the apex, (*b*) to the fact that the apex is sometimes slightly displaced by interfering cavity tones.

2. The general character of muscular action forces us to assume that the changes in the voice proceed with some regularity; this would indicate that the unusual figure 2.6 for the sixth period does not give the proper period at that point but shows something else.

Using ZIMMERMANN's table for 16, the figures in column *A* are turned into time by the equation $1^{mm} = 0.0016^{s}$, with the results given in column

[1] This Plate and much of the analysis were first published in SCRIPTURE, *Speech curves, I*, Mod. Lang. Notes, 1901 XVI 72.

[2] The system of phonetic notation is that used in SCRIPTURE, Elements of Experimental Phonetics, New York 1902.

A Period in millimeters.	*B* Period in seconds.	*C* Frequency.	*A* Period in millimeters.	*B* Period in seconds.	*C* Frequency.
3.8	0.0061	167	4.8	0.0077	130
3.8	0.0061	167	5.0	0.0080	125
3.9	0.0062	161	5.1	0.0082	122
4.0	0.0064	156	5.0	0.0080	125
4.0	0.0064	156	5.1	0.0082	122
2,6			5.2	0.0083	120
4.2	0.0067	149	5.1	0.0082	122
4.2	0.0067	149	4.7	0.0075	133
4.1	0.0066	152	4.6	0.0074	135
4.0	0.0064	156	4.7	0.0075	133
4.2	0.0067	149	4.8	0.0077	130
4.3	0.0069	145	4.7	0.0075	133
4.3	0.0069	145	4.4	0.0070	143
4.2	0.0067	149	4.5	0.0072	139
4.3	0.0069	145	4.5	0.0072	139
4.3	0.0069	145	4.5	0.0072	139
4.3	0.0069	145	4.7	0.0075	133
4.1	0.0066	152	4.5	0.0072	139
4.2	0.0067	149	4.7	0.0075	133
4.3	0.0069	145	4.5	0.0072	139
4.5	0.0072	139	4.6	0.0074	135
4.5	0.0072	139	4.4	0.0070	143
4.5	0.0072	139	4.6	0.0074	135

B. These are the lengths of successive periods in the cord tone. Using a table of reciprocals (Barlow or Zimmermann) these are turned into frequencies by the equation $C = 1/B$, with the results given in column *C*.

The curve of frequency is now to be plotted. This is best done by supposing the speech curve to be laid off along the horizontal or X axis, so that the first vibration is at zero. Above zero the proper number of millimeters is counted upward to indicate the frequency of the cord tone at the start. Thus, if the period of the first group is 0.12^{s}, the frequency will be 83; if 100^{mm} have been assigned to each 100 of frequency, the dot will be placed at 83^{mm} above the X axis. Above the point on the X axis at which the second group of vibrations would begin if the curve were laid upon it, the frequency of the cord tone at this moment is indicated by a dot at the proper height. In this manner a series of dots is obtained, indicating the frequency of the cord tone at a succession of moments. (Plate XIV, Fig. 1.)

In the diagram of frequency the successive dots might be connected by straight lines. We probably come nearer to the true curve of frequency by drawing a smooth curve that evenly distributes the dots on either side. This may be done with the free hand, by means of draughtsman's curves, or by a flexible rubber ruler; the more general reasons for this procedure may be found in works on the methods of science.[1] The curve of frequency of *ɔhi*, plotted from the table on p. 57, is shown in Plate XIV, Fig. 1.

The curious interruption of the regular course of figures in the table by 2.6 arises from the fact that the series of the strongest vibrations used to mark off the groups is replaced at this point by a series arising from one of the weaker vibrations. In the first part of the curve there is some vibration of a changing character that causes a change in the moment of strongest vibration. The unusual figure indicates this latter fact and not any sudden break in the cord tone. A similar occurrence may be seen in *o* of "bow" at the middle of line 2 (Plate I) and in *ɔ* of "draw" as indicated below.

The periods of the smaller, or cavity, vibrations can frequently be obtained by direct measurement. This occurs most readily when these vibrations are of a simple form or of a pitch much higher than the cord tone. The result becomes more accurate when several successive cavity vibrations can be measured together. When the cavity vibrations are simple in form and a place in the curve can be found where a number of them exactly fill out a group period, the length of the group period divided by the number of vibrations will give the length of the cavity period.

No detailed study of the specific sounds will be undertaken on the present occasion; this will be done in the near future, as soon as the enormous labor of analyzing the similar sounds of several speakers has been completed. One sound, however, calls for special attention, namely, the sonant *h*.

A faint *h* is distinctly heard between *ɔ* and *i* in "saw him"; the observation has been verified by several listeners. There is no interruption of the vibrations between the two vowels, but a slight weakening occurs near the middle of the record. The *h* is thus a sonant one. Other cases are to be found in "saw him" of Plate II and "had" of Plate VII. PIPPING[1] records a similar case in a record of Finnish "keihäitä."

[1] JEVONS, Principles of Science, Chap. XXII.

[2] PIPPING, *Zur Phonetik d. finn. Sprache, Unters. mit Hensen's Sprachzeichner*, Mém. de la Soc. finno-ougrienne, XIV, Helsingfors 1899.

Sonant *h* was regularly prescribed by the Sanskrit grammarians.[1] It is used in some modern languages.[2]

The curves of the vowel sounds of the word "bow," of the phrase "with my bow and arrow," are shown in the second and third lines of the Plate. To the ear the word appears melodious and prolonged; it might even be called mellifluous.

The tracing begins with three faint vibrations that presumably occur as the mouth begins to open after the occlusion for *b*. Thereafter the vibrations follow in groups of four, beginning with a length of 5.5^{mm} and decreasing slowly to 4.8^{mm} in the middle of the line; this indicates a cord tone of rising pitch. The cavity tone remains practically constant at 1.5^{mm} per vibration, or a period of 0.0024^{s}, or a frequency of 417.

The amplitude rises steadily to a degree that indicates considerable loudness; it then falls rather suddenly (middle of second line in Plate I). The vibrations beyond this point show so many peculiarities that their difficulties can best be attacked by working backward from a later point where the grouping is more regular. Somewhat beyond the middle of the second line in Plate I the vibrations fall into groups having two main crests with two subordinate ones. This entire group arises presumably from one cord vibration. This conclusion is drawn because further on to its right the group gradually changes to two main crests only, a typical form for a cord tone accompanied by a cavity tone nearly an octave higher. This condition of a cord tone with an octave cavity tone is modified in the first part by higher tones that do not form an exact harmonic interval with either of the other tones; these give rise to the minor fluctuations in the middle of the line. These higher tones are of changing pitch, as can be seen by the steadily changing form.

The puffs of air from the cords are not generally of the even nature found in sinusoid vibrations;[3] they rather resemble more or less sharp explosions.[4] In this sound they are not so sharply explosive as in *au* of "shroud" or *æ* of "sparrow," yet the puff has its greatest intensity in the first part of the interval of time it occupies.

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[1] For examples see Tâittirîya Prâtiçâkhya, II. 47, ed. by WHITNEY, Journ. Amer. Oriental Soc., 1871 IX 77.

MICHAELIS, *Über das H und die verwandten Laute*, Arch. f. d. Studium d. neueren Sprachen (Herrig), 1887 LXXIX 49, 283.

[2] MEYER, *Stimmhaftes H*, Neuere Sprachen, 1900 VIII 261; *tsum ſtimhaſtn ha*, Maître phonétique, 1901 XVI 87.

KLINGHARDT, *Stimmhaftes H*, Neuere Sprachen, 1901 IX 85; PASSY, *H vocalique*, Neuere Sprachen, 1901 IX 245.

[3] SCRIPTURE, Elements of Experimental Phonetics, 2, New York 1902.

[4] SCRIPTURE, as before, 260.

Starting from the strong vibrations (third quarter of line 2), we mark off backward the alternate higher vibrations as the points of maximum for each cord puff. We thus have the vibrations in pairs; the period of the cord tone at any moment will be given by the distance between two such marked vibrations.

As we go towards the left, we see that each of the vibrations of a pair shows a tendency to split up into two minor vibrations; this indicates the presence of higher cavity tones. Measurements of the periods of the cord tone show that it steadily rises in pitch (Plate XIV, Fig. 2).

The alternate (or cavity) vibration keeps very closely at the middle of the cord period; though in the first portion it is generally a little behind the middle point. This indicates a cavity tone in general an octave higher than the cord tone, but a little lower in the first portion. The details can be brought out by measurements.

In addition to the two maxima of amplitude in line 2 there is a third maximum in line 3. It may be suggested that perhaps this vowel sound is to be considered as a triphthong. Careful listening to the gramophone plate enables the ear to hear two maxima clearly and the third faintly. The maxima are due, not to any breath emphasis, but to coincidence of the cavity period with a submultiple of the cord period. [1]

The word "shroud" occurs in "Who'll make his shroud?"

One pseudobeat for the *r* occurs at the flat place in line 4. The vibrations in line 3 and at the beginning of line 4 belong to the vowel-like sound in connection with which the flaps of the *r* occur. After the occlusion of the pseudobeat the tongue again allows the cord- and cavity-vibrations to appear. The form of the vibration is different, indicating a changing adjustment of the mouth from the *r* position to the *a* position; this position is to be considered as the *r-a* glide. There is no possibility of limiting the *r* from the *a*, or of marking off a distinct *r-a* glide; the change is gradual throughout.

The *r-a* glide after the flap is followed by the long record for *au* reaching to the middle of line 5. The latter part of line 5 contains the faint vibrations of the *u-d* glide, the still fainter ones of the *d*-occlusion, and the strong ones of the *d*-explosion.

The curve of frequency is shown in Plate XIV, Fig. 3. During *au* the cord tone rises from 120 in frequency to 111 and then falls steadily to 92. The diphthongized vowel *au* is thus of circumflex pitch. In *d* the cord tone rises to 109.

The *au* is of crescendo-diminuendo intensity, the crescendo being gradual and the diminuendo rather sudden.

[1] SCRIPTURE, as before, 13.

The word "sparrow" occurs in "I, said the sparrow." The *æ* begins at the first quarter of line 6. The first few cavity vibrations show a changing form as the *p* glides into the *æ*. The *æ* ends at the last quarter of line 6; here the cavity vibrations again change their forms as the *æ* becomes *r*. The *r* has one flap. This does not produce absolute silence, as some vibrations can still be detected in the tracing. The very long *o* extends over the last fifth of line 6 and nearly all of line 7. In general the curve of this *o* differs considerably in the details of the cavity vibrations from that of *o* in "bow" (above); it has none of the large and sudden changes in amplitude.

The curve of frequency of the cord tone is shown in Plate XIV, Fig. 4.

The cord tone starts at *æ* with 125 in frequency, rises to 202, and then falls slowly to 136 at the end of *o*. The amplitude of *æ* increases slowly, then falls suddenly, and becomes almost zero at the end of the *æ·r* glide. The amplitude of *o* increases quite rapidly and continuously during the *o* to a maximum beyond which it gradually decreases as the vowel fades away in its gradual exit.

The words "draw your" occur in the introduction "Now, children, draw your little chairs nearer." The last five lines give the curve for nearly all of *ɔju*, omitting a piece at the end. The recording surface was run at a greater speed than for the previous curves; the space-time equation is $1^{mm} = 0.0007^s$. This speed is more favorable for the details of vibrations of greater amplitude but less favorable for those of smaller amplitude.

The analysis of the curve may be approached in the following way. The vibrations in the latter portion of the eighth line are evidently to be grouped in threes. There is present here a cord tone with a cavity tone a duodecime above it. The last group on this line has a length of 10.2^{mm}, indicating a cord period of 0.0071^s, or a frequency of 143. Measuring backward we find that the preceding group is a little longer than this one; in fact each group is found to be a little longer than the following one. The cord tone is thus shown to be rising in pitch.

The three small vibrations that make up the last group on line 8 are nearly equal in length although the last one appears to be cut off somewhat by the following stronger vibration of the next group. The preceding group shows nothing of the cutting off. The next preceding group shows that the three small vibrations do not quite fill out the interval between the apexes of two strong vibrations selected to mark off the groups. This becomes still more evident in the further preceding groups. This condition seems to indicate that the small vibrations composing a group retain a constant period while the length of the

group is changing. In confirmation of this we finally find four small vibrations instead of those in the early part of the vowel. The period of the small vibrations is approximately 0.0028^s, giving a frequency of 357. This is a very clear illustration of the fact that the cavity tones of vowels are independent of the cord tone in regard to pitch, and are not overtones of it as commonly supposed.

That there are still other resonance tones is indicated by minor deformations of the curve, but further information concerning them is not obtainable at present.

Proceeding onward, we find that the cord tone continues to rise. At the first quarter of line 9, the length of a group is 9.0^{mm}, giving a period of 0.0063^s, or a frequency of 159; at the third quarter the length is 8.0^{mm}, the period 0.0055^s and the frequency 179. The tone now rises more slowly. At the first quarter of line 10 the length is 7.5^{mm}, the period 0.0053^s, and the frequency 189. Beyond this point the tone remains nearly constant.

In the meantime the cavity vibrations have been undergoing a change. Instead of one cavity tone, two begin to show themselves distinctly. The most powerful one appears as a fairly strong vibration at 50^{mm} (0.0035^s) after each strongest vibration in the group. Although the group shortens, this vibration remains at a nearly constant distance from the beginning, necessarily, however, approaching closer and closer to the end of the group. The strong secondary vibration has been observed[1] in many cases of *a* in *ai*. In those cases it remained at a constant distance from the beginning of the group till the group became so short that it coalesced with the strongest vibration of the following group. Here the result is different. Instead of remaining at an absolutely constant distance behind the preceding strongest vibration of the group, it gradually, but not greatly, lessens the distance till, as the cord tone becomes stationary in pitch, it ultimately occupies the middle of the group as the octave of the cord tone. But another change has taken place that is of a puzzling nature; this strong secondary gradually becomes stronger than the other vibrations in the group. This can be readily seen by checking off the strongest vibrations in line 9 as boundaries of groups beginning at the left; in the middle it will be found that one vibration has become stronger than the ones that must be checked off as boundaries of groups. An explanation of this phenomenon is lacking.

The cord tone remains constant with a period of about 0.0053^s throughout line 10. The cavity tone at an octave above also remains

[1] SCRIPTURE, *Researches in experimental phonetics (first series)*, Stud. Yale Psych. Lab., 1899 VII 26.

unchanged. The other cavity tones that produce the small marked inflections in line 9 and line 10 gradually die away, leaving the vibrations grouped in pairs at the end of line 10.

In line 11 the vowel somewhat suddenly decreases in amplitude. It is followed by the small vibrations of the weak (but not very short) *j* that precedes *u* in "your."

Line 12 shows the vowel *u* of "your";the curve is not completed.

The curve of frequency is given in Plate XIV, Fig. 5. The cord tone rises from about 75 in frequency at the beginning of *ɔ* (line 8) to about 189 (line 10), after which it remains practically constant until it begins to fall in the *ɔ-j* glide (last part of line 10). During *j* and *u* the tone falls steadily.

The curves in Plate II are from the words: "I" in "I, said the beetle," "my" in "with my bow and arrow," "parson" in "I'll be the parson," "saw him" in "I saw him die," "caught" in "Who caught his blood?" and "said" in "I, said the rook."

The curve for "I" shows a series of vibrations in which each group resembles the neighboring one, while there is a gradual change in character from a typical form for the *a* in the first part to a typical form for the *i* in the second part of the diphthong *ai* of which the pronoun "I" is composed. In the first portion there appears a succession of strong vibrations, each followed by a series of weaker ones. These strong vibrations recur at periods of steadily decreasing length.

If we consider separately each group of vibrations beginning with a strong one, we find that it is, aside from minor details, the typical curve[1] of a vibration initiated by a blow and dying away by friction, for which the equation is

$$y = a \cdot e^{-kt} \cdot \sin 2\pi \frac{t}{T},$$

where y is the elongation at the moment t, a the amplitude, e the basis of the natural series of logarithms, k a factor representing friction and T the periodic time.

The succeeding groups of vibrations following the first group are of the same form but of steadily increasing amplitude. They recur at steadily decreasing intervals. The formula for each group is approximately the same except for the difference in amplitude. The vibrations are evidently aroused by a series of blows of steadily increasing strength at steadily decreasing intervals.

It seems clear that these vibrations represent the free vibrations of the

[1] SCRIPTURE, Elements of Experimental Phonetics, 6, New York 1902.

air in the mouth cavity aroused by a series of sudden blows and that these sudden blows are due to explosive openings of the vocal cords.[1]

The tone from the cords results from the succession of groups of vibrations; it is a tone of intermittence. The period of the tone from the cords is represented by the distance from the strong vibration at the beginning of each group to the strong one at the beginning of the following group.

The complexities of the small vibrations indicate the presence of several partial tones. These complexities change steadily from the beginning of the vowel onward as the pitch rises, in a way to indicate the presence of at least the following partials: 1. the fundamental cord tone consisting of a series of explosions rising from a period of 0.0170^s (frequency, 59) to one of 0.0052^s (frequency, 192); 2. a constant cavity tone of 0.0034^s period (frequency, 294) shown by the large secondary; 3. a constant cavity tone of 0.0013^s period (frequency, 769) shown by the smaller vibrations, and 4. higher cavity tones undergoing change.[2]

The minor complexities in the vibrations disappear at about one-quarter of the distance from the left on the second line in the figure. At the same time the amplitude is strongly increased. Shortly afterward the amplitude decreases and finally reaches zero. Throughout the whole latter portion the curve has an entirely different character from that of the first half; we are probably quite safe in considering it the curve of *i* in the diphthong *ai*. Throughout the *i* the groups consist of two vibrations, one slightly stronger than the other. The period for the group 0.0052^s (frequency, 192) remains constant till near the end, where it lengthens to about 0.0122^s (frequency, 82). The cavity vibration forming half of each group remains constant at 0.0026^s (frequency, 384) through nearly all of the *i*. Toward the close it apparently still remains at the same period, producing phenomena of interference as the group period is lengthened.

From the curve for *i* it seems justifiable to conclude that the vocal cords emit explosions instead of sinusoid puffs of air here as well as in the *a*. The explosion produces a strong free vibration in the mouth cavity which is followed by another of diminished amplitude. This would be followed by a third of still less amplitude, just as in *a*, but a new explosion from the cords occurs at just that moment. The coincidence of double the period of the cavity tone with the period of the cord explosions explains the rapid gain in amplitude when the cord tone rises sufficiently to produce the coincidence (p. 62). The maximum is followed by a relaxa-

[1] SCRIPTURE, as before, 260.

[2] SCRIPTURE, as before, 91.

tion in the force of breath, but the two tones maintain the same relation for a considerable time. As the sound finally dies away, the cords also relax, both breath and pitch falling together. The explosions from the cords seem much less sharp in *i* than in *a*.

In "my" the *m* vibrations are too faint for accurate measurement. The *a* resembles somewhat, but not closely, the *a* of "I." The period of the cord explosions remains constant at 0.0074^s (frequency, 135) instead of decreasing. The lower cavity tone has a period in the neighborhood of 0.0022^s (frequency, 455); it apparently undergoes a slow change from the beginning of the *a* to the *i*.

The last third of the curve somewhat resembles the *i* portion of "I." There is, however, only a faint rise in amplitude, and the *i* portion is very brief. The vibrations in this portion are in groups of three; the groups have a period of 0.0074^s (frequency, 135) constant to the end. The vibrations within the group have a period one-third that of the group itself, indicating a constant cavity tone of 0.0025^s (frequency, 400).

In the *a* of "parson" the cord tone rises from a period of 0.0090^s (frequency, 111) to one of 0.0072^s (frequency, 139) and falls again to the pitch from which it started. There are indications of a constant cavity tone of 0.0022^s (frequency, 455) and of higher tones with changing periods. In respect to the pitch of the lowest cavity tone there is close agreement of this *a* with that of "my," yet the form of the curve resembles that of *a* in "I" more closely than that in "my." The peculiarity of "my" seems to lie chiefly in the suddenness with which the vibrations within a group fall in amplitude after the initial strong vibration. In both "parson" and "I" the cavity vibrations within each group during *a* die away less quickly. Such differences may perhaps find their explanation either in the greater friction on the free vibratory movement in the mouth (less rigidity of the walls?) or in the sharper character of the cord explosions in the case of "my."

The curve for *ɔ* in "saw him" indicates a quite different vocal action from that present in *a*. Instead of a strong initial vibration followed by decreasing ones the earlier portion of the vowel shows groups that contain at least two strong vibrations. It is presumably the case that the cord explosions are of a more gradual character or else that the action of friction is much less. Even later in the vowel where there is apparently only one very strong vibration in a group, this probably occurs because the lower portion of the second one is cut off by interference with another partial tone.

The cord tone, starting with a period of 0.0072^s (frequency, 179), remains at this pitch for a time and then falls to 0.0080^s in period

(frequency, 125). The lower cavity tone with a period of 0.0026^s (frequency, 385) is apparently present.

The last part of the line shows the vibrations for *i*, resembling those for *i* in *ai* of "I" and "my." The middle portion, where there is a weakening in amplitude, belongs to the sonant *h* (p. 58). The *m* is just begun where the record is cut off. The grouping in the *i* is by threes. The cord tone of *i* starts with a period of 0.0083^s (frequency, 121) and steadily rises to one of 0.0072^s (frequency, 139) in the *m*. The lower cavity tone has a period of about 0.0025^s (frequency, 400).

The curve for the *ɔ* of "caught" exhibits a decided difference from that for the *ɔ* of "saw," although both vowels are generally considered to be the same. The *ɔ* of "caught" shows a quick and strong increase in amplitude followed by a rather sudden decrease. Its pitch is approximately constant. The initial strong vibration of a group is followed by very much weaker vibrations; the cord action resembles that in *a* rather than in the *ɔ* of "saw." In the last few groups there is a marked change as the *ɔ* alters to *t*.

The cord tone rises from a period of 0.0074^s (frequency, 135) to one of 0.0064^s (frequency, 156) but falls again in the last few periods. The lower cavity tone seems to have a period of about 0.0024^s (frequency, 417). Other tones of higher pitch are present.

In the *e* of "said" the vocal action is seen to differ essentially from that in *a* or *ɔ* and to resemble somewhat that in *i*. There is much less indication of the explosive character of the cord tone. There are three cavity vibrations to each group. The pitch of the cord tone is nearly constant at 0.0072^s period (frequency, 139); the lower cavity tone has a period of 0.0024^s (frequency, 417). There are minor fluctuations in the curve that indicate higher cavity tones. The amplitude increases steadily until the vowel is ended rather abruptly by the change to *d*.

IV. Studies of the Jefferson curves.

Joseph Jefferson[1] was born at Philadelphia in 1829. He grew up in the midst of theatrical surroundings. He was brought on the stage at the age of four, and showed unusual imitative ability. His most famous part is that of Rip Van Winkle in the play of that name.

Joseph Jefferson's great-grandfather, Joseph Jefferson, was an English actor of prominence. His grandfather, Joseph Jefferson, was born at Plymouth, England; as a lad he acted upon the stage; at about twenty years of age he migrated to America where he achieved dis-

[1] Jefferson, The Autobiography of Joseph Jefferson, New York 1889.
Winter, The Jeffersons, Boston 1881.

tinction as an actor; he married the American-born daughter of an emigrant Scotch merchant. His father was Joseph JEFFERSON, an American actor and painter.

His maternal grandfather and grandmother were French. On a journey from France to San Domingo a daughter was born to them in New York City. They resided in San Domingo till 1803, after which they lived in Charleston, South Carolina. The daughter, Cornelia Frances Thomas, won an excellent rank in Charleston as an actress and a singer. Her first husband was the Irish comedian, Thomas Burke. Her second was Joseph JEFFERSON, father of the speaker of these records.

Owing to his mixed ancestry, to the constant wanderings of his parents and himself, and to the actor's tendency toward freedom from dialectal peculiarities, JEFFERSON's speech is typically American in every sense that can be given to the term.

A gramophone disc, numbered 698 Z, containing *Rip Van Winkle's Toast* spoken by Joseph JEFFERSON was traced off by the machine shown in Fig. 1. The words on the plate were "Come, Rip, what do you say to a glass? What do I say to a glass? Huh, now what do I generally say to a glass? I say it is a fine thing—when there's plenty in it. Ha! So. You had it ten years ago, eh? Ah. That's fine schnapps. I wouldn't keep it as long as that, would I? Huh, huh. Well, here's your good health, and your family's; and may they all live long and prosper. Ah." The complete tracing is reproduced in Plates III to XI. Each group of words on these plates refers to the following portion of the curve. The figures show the number of millimeters of straight line cut out of the record.

A. The melody of *Rip Van Winkle's Toast.*

After a general analysis[1] of the record the lengths of the successive groups of vibrations were carefully measured in tenths of a millimeter. The lengths were turned into time by the equation $1^{mm} = 0.0007^{s}$; the results were the periods of the cord tone. The reciprocals of the periods gave the frequencies. For example, a group of vibrations corresponding to one explosion from the cords measured 0.0038^{mm}; multiplied by 0.0007 this gave a period of 0.0061^{s}, and $1 \div 0.0061$ gave a frequency of 167. The curve of frequency (pitch, or melody) was plotted by supposing the original speech curve, as in Plates III to XI, to be laid along a horizontal axis, and erecting above the beginning of each group an ordinate proportional to the frequency. In this way the curve of frequency for the entire set of plates was plotted on a strip (over 17

[1] The methods of analysis are described in SCRIPTURE, Elements of Experimen al Phonetics, Ch. V, New York 1902.

meters long) of millimeter paper. This was then divided into convenient pieces and made into two blocks (Plates XII and XIII) with a reduction to one-fifth. The horizontal scale of time in the melody plates is thus $1^{mm} = 0.0035^s$, or *one-fifth* that in the original speech plates. The dots of the plot were joined by straight lines. This gives the results accurately; but a more truthful representation of the melody-effect would be made by a curve running smoothly through the dots (p. 58).

The vertical scales indicate frequency, or the number of vibrations a second. Each group of words refers to a portion of the melody-curve extending from its beginning to a group of large figures on the horizontal line; during each portion the horizontal line remains unbroken. The large figures indicate, as in Plates III to XI, the portions of straight line in the original tracings that were omitted in preparing the plates; they may be turned into time by the original equation of $1^{mm} = 0.0007^s$.

The interruptions in the melody-curve indicate surds, or very weak sonants, or pauses.

The curve in Plates XII and XIII shows a very low and even melody of speech that is varied at times for emotional expression. In general each sentence begins low, rises gradually, and then falls; but variations occur. The changes in the tone are usually continuous.

"Come Rip" shows a rise at the end, which is a common inflection for a cheerful, animated invitation. "What do you say to a glass?" shows a low vowel, then a rise to the *u* of "you"; this *u*, however, begins to fall just before the following word. "Say" is of high pitch, as is frequently the case for the verb of a question; the fall at the end of "you" may have been a kind of preparation by contrast for the high pitch of "say." The highest pitch for the phrase is found in "glass"; it is even higher than in "say," probably because of the greater emphasis given to the word "glass." The pitch falls toward the end of *æ* in "glass"; such a fall is usual in a sentence beginning with an interrogative word or phrase that is not especially emphatic. These words were spoken by JEFFERSON as introductory to the *Toast* itself. The invitation is followed by a long pause of 2.86^s before the reply comes.

The toast begins with a repetition of the question of invitation. It is spoken in a rather soft manner, as appears not only to the ear but also in the small amplitude of the waves in Plate IV. The pitch curve is fairly evel, with some rise at the end instead of a fall. This rise is the usual ending of a repeated interrogative sentence. The general pitch is lower than that of the invitation. A pause of 0.41^s follows.

The exclamation "Huh" is a kind of chuckle. It is of a very high

pitch but small intensity and short duration. It is followed by a pause of 1.05^s.

"Now what do I generally say to a glass?" shows a very even rise and a very gradual fall; its general pitch is low. It is a kind of bantering statement. The long pause of 2.16^s seems to express a simulated expectation of a reply.

"I say it is a fine thing" is a decided statement with emphasis on "fine thing." It has the usual circumflex form as far as "a." If the sentence had been completed with no further emphasis, the pitch would probably have continued to fall. The rise in pitch for the specially emphatic "fine thing" adds an accessory circumflex. The pause of 1.78^s and the fall in pitch lead the hearer to suppose the sentence finished.

"When there's plenty in it" is muttered as a joke. Its pitch is not lower than usual. The emphasis "plenty in it" gives a higher pitch to the latter portion. The whole statement has the usual circumflex form. The long pause 2.90^s is presumably occupied by the first sip of the toast.

The soft exclamation of satisfaction "ha" has a falling pitch. It is followed by a pause of 1.79^s. The "so" expresses deep satisfaction. It begins moderately high and falls steadily in pitch. To the ear it has a peculiar rattle of a low pitch as if some particles of liquor had lodged on the edge of the epiglottis, as is sometimes the case after drinking. This peculiar effect shows itself in the alternately louder and weaker character of the groups of vibrations as seen in Plate VII. Such a curve could be produced by the cord explosions striking against a mass of liquid that would vibrate readily at a submultiple of the cord period; the portion of liquid would rise and fall, weakening the cord tone on alternate periods. It is probable that when speaking into the gramophone recorder JEFFERSON produced this effect by some muscular adjustment (epiglottis, ventricular bands) and not by an actual sip of liquid. "So" is followed by a pause of 2.00^s.

"You had it ten years ago, eh?" is spoken as a continuous sentence; there is complete fusion of the vowels at the end. The first part rises rapidly to a high pitch. The circumflex form is marked, the fall beginning in the *o* of "ago." The "eh" has a circumflex form joined to the *o* curve. In spite of the complete fusion of these vowels we may perhaps consider "eh" as a stressed tag with a pitch-curve of its own. The sound indicated here by "eh" begins with a very weak breathing and seems slightly nasalized. The long pause of 2.45^s indicates perhaps the time of another sip.

"Ah" is an expression of satisfaction; it appears to the ear much lower and smoother than the "ha." The following pause is very short, 0.13ˢ.

"That's fine schnapps" is not an emphatic statement but expresses a decided conviction after a satisfactory trial. It shows the usual initial rise for a declarative sentence, but instead of falling at the end, it rises slightly. This peculiar rise seems to express conviction after a doubt. The figures 333ᵐᵐ after "that's" indicate the portion of tracing (*tsf*) left out in the original record, and not a pause. The sentence is followed by a pause of 1.92ˢ.

"I wouldn't keep it as long as that" has the usual circumflex form; it is followed by a brief pause of 0.29ˢ.

"Would I" is used to turn the declaration into question. It is very brief. A short pause, 0.25ˢ, follows.

The very brief and faint chuckle "Huh, huh" is followed by a pause of 1.20ˢ.

The introductory "Well"—presumably spoken as the glass is lifted—rises steadily to a high pitch. It is followed by a long pause of 3.43ˢ.

"Here's your good health" rises steadily to a very high pitch. The speaker makes a rather long pause, 0.94ˢ, perhaps for emphasis. He then completes the thought in his mind by "and your family's." This tag-phrase has, however, somewhat the character of a separate sentence; its pitch-curve is circumflex. It is followed by a pause of 1.54ˢ.

The invocation "and may they all live long and prosper" appears to have the solemn steady intonation of a somewhat religious utterance. The pitch-curve shows great evenness; there is a rise at the beginning and a fall at the end. The fall appears during the first part of "prosper"; during the last part the cords have so relaxed that they produce only a few rather irregular vibrations (Plate XI); this last syllable appears to the ear almost as a surd or whispered one. It is followed by a pause of 1.74ˢ, during which the toast is presumably drunk.

The "ah" is a low, soft exclamation of gustatory satisfaction after the toast. The peculiar rattle is heard as in "so" above; the same alternation in the character of the groups of cord vibrations appears. The pitch-curve shows a steady fall. The last vibrations are of a very low pitch; they appear clearly in the tracing but they are probably too low for the ear to catch.

B. Duration of sounds in *Rip Van Winkle's Toast.*

Measurements of the lengths of the speech sounds in the JEFFERSON records were made by an assistant under my guidance. The complete-

TABLE.

k	?
ə	0.22[a]
m	.11
ɹ	.15
i	.21
p ч *hw*	.33
ə	.19
d	.06
ə j u	.66
s	.24
e	.24
t	.10
u ə	.31
g l	.14
æ	.57
s ч *hw*	3.94
ə	.19
d u a i	.43
s	.16
e	.21
t	.10
u ə	.30
g l	.10
æ	.45
s ч *h*	.46
ə	.16
ч *n*	1.28
au	0.22
hw	.04

ə	.22
d	.02
u a i j e n ɹ ə l i	1.33
ч *s*	.14
e	.22
t	.07
u ə	.25
g·	.02
l	.11
æ	.35
s ч	2.23
a i	.25
s	.11
e i	.25
t_*	.05
i	.16
z	.04
ə	.13
f	.10
a i	.33
n θ	.10
i	.29
ŋ	.10
ч *hw*	1.90
e	.16
n ð	.13
ə	.14

z p	.18
l	.03
e n t	.22
i i n i	.45
t ч *h*	3.07
a	.32
ч *s*	1.86
o	.49
ч	2.06
j u h æ	.39
d	.06
i	.11
tt	.19
e n j i ə	.70
z	.02
ə	.08
g	.09
o *e*($ə^n$?)	.80
ч	2.52
a	.52
ч *ð*	.19
æ	.22
t s f	.26
a i	.23

n	.14
š	.12
n	.09
æ	.24
p s ч	1.97
a i	.30
w	.07
u	.11
d	.03
n	.16
t k	.11
i	.13
p i t	.06
æ	.11
z	.06
l	.24
ɔ	.34
ŋ	.07
ə z ð æ	.93
t ч *w u d*	.32(?)
a i	.09(?)
ч	.30
həhə	.13
ч *w*	1.14
e	.32
l ч *h*	3.56
i ə	.29

z	.09
j u	.24
g	.02
u	.16
d h	.03
e	.30
l	.07
θ ч	.97
ə	.16
n	.16
j uə	.14
f	.12
æ	.23
m	.07
ə	.06
l	.08
i	.13
z ч	1.64
æ	.01
n m	.12
e	.16
ð	.05
e	.31
ɔ ll i	1.76
v	.10
l	.18
ɔ	.62
ŋ ə n	.34
ч *p r*	.10
a	.30
s	?
p	?
ə	?

ness of the fusion of sounds in connected speech[1] made it impossible to assign any very definite limits to most of the sounds. When a sound was next to a pause or a surd, its limit was placed at the extreme vibration. Thus the first vibration of *ə* in "come" (Plate III, line 1) and the last distinct one of *i* (line 4) gave fairly definite limits. Yet the curve shows quite clearly that the *i*-vibrations began to be weakened by closure for the *p* somewhere about 60^{mm} from the right end of line 4; faint vibrations can, however, be detected at about 15^{mm} from the end; thus, even in a case like this, it is impossible to mark off the limits of *i*, *i-p* glide, and *p*. In other cases there is no possibility of assigning any limits, because the sounds are fused into gradually changing ones; thus in line 13 the *u* of "to" changes to *ə* "a," but the change is a gradual one beginning far back in the *u* and extending throughout the *ə*. In fact, there are *not* two sounds *u* and *ə* united by a glide; there is a changing sound which at some one instant may be an *u* and at a later one may be an *ə*, and which to the ear (trained to various associations) gives an impression resembling a sequence of *u* and *ə*. In spite of these facts I venture to give figures for the duration of sounds in these JEFFERSON records in order to furnish some approximate data; the figures are subject to the limitations just explained; where I have been utterly unable to decide on a limit I have indicated the fusion by a brace in the Table.

The phonetic notation is used in the Table merely to indicate the sounds in order to aid in marking off their duration; it is not intended as an accurate phonetic analysis. For example, the use of *ə* for the short vowel in "what" does not necessarily mean that the sound is identical with the *ə* in "come"; to the ear the brief vowel in this case seems related to *a*, *ɔ*, and *ə*, but it is hardly possible to decide on the degrees of likeness. The symbol t_* indicates a sonant *t*.

V. STUDIES OF VIBRATING SPRINGS.

According to the HELMHOLTZ theory[2] a vowel is produced by a cord vibration of the nature of a sinusoid or a harmonic series of sinusoids acting on a resonating cavity or on a set of such cavities. The method of manufacturing a vowel by synthesis of tones would, if this theory were

[1] SCRIPTURE, Elements of Experimental Phonetics, 452, New York 1902.

[2] HELMHOLTZ, *Über d. Vokale*, Arch. f. d. holl. Beitr. z. Natur- u. Heilk., 1857 I 354.

HELMHOLTZ, *Über d. Klangfarbe d. Vokale*, Gel. Anz. d. k. bayr. Akad. d. Wiss., 1859 537; also in Ann. d. Phys. u. Chem., 1859 CVIII 280, and in Ges. wiss. Abhandl., I 395, 397, Leipzig 1882.

HELMHOLTZ, Die Lehre v. d. Tonempfindungen, 5. Aufl., 168, Braunschweig 1896.

true, consist in adding tuning-fork tones of different pitches and intensities. This was attempted in HELMHOLTZ's vowel apparatus.[1] The method of manufacturing a curve like a vowel curve would, if the theory were true, lie in adding sinusoid vibrations of different periods and amplitudes. This was attempted with the harmonic curve adder of PREECE and STROH.[2] HELMHOLTZ's synthesis succeeded only for *u* and *o*; it failed for all other vowels. PREECE and STROH produced curves that at best only distantly resembled vowel curves. The theory thus failed in both cases.

According to the WILLIS-HERMANN theory[3] the cords emit puffs of greater or less sharpness, which act on the vocal cavities like sharp blows. I have attempted to construct a vowel machine on this principle; the

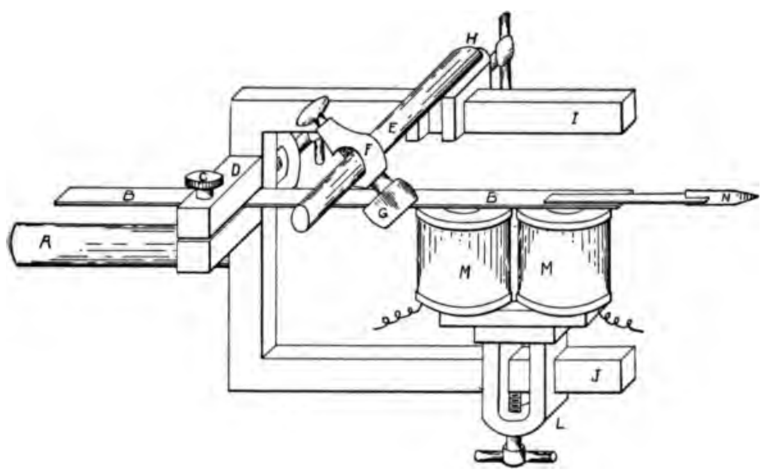

FIG. 10.

account will be given later. I have also attempted to manufacture vowel curves by vibrating springs moved by sharp blows; on the present occasion I will describe the apparatus and give some of the earlier results.

The steel spring *B* (Fig. 10), clamped tightly in a small vise *D* on

[1] HELMHOLTZ, Die Lehre v. d. Tonempfindungen, 5. Aufl., 200, Braunschweig 1896.

[2] PREECE AND STROH, *Studies in acoustics, I. On the synthetic examination of vowel sounds*, Proc. Roy. Soc. Lond., 1879 XXVIII 358.

[3] WILLIS, *On vowel sounds and on reed-organ pipes*, Trans. Camb. Phil. Soc., 1830 III 231; also in Ann. d. Phys. u. Chem., 1832 XXIV 397.

HERMANN, *Phonophotographische Untersuchungen*, Arch. f. d. ges. Physiol. (Pflüger), 1890 LVIII 274.

HERMANN, *Phonophotographische Untersuchungen*, Arch. f. d. ges. Physiol. (Pflüger), 1894 LXXIV 380, 381.

the frame IJ, bears at its end a recording point N of thin steel ribbon. The frame also carries an adjustable electro-magnet M clamped in place by L and a felt damper G adjusted as desired by the clamps F and H with their rod E. The rod A is placed in a supporting standard (Fig. 11),

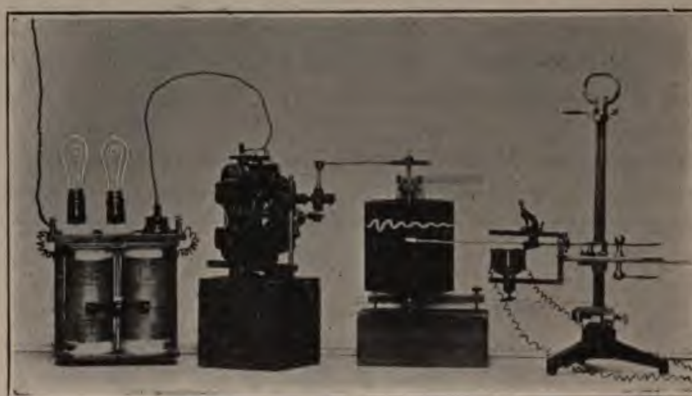

FIG. 11.

which is so adjusted that the recording point rests against the surface of a smoked drum.

The drum is rotated by a small electric motor whose speed is regulated by an appropriate resistance ; Fig. 11 shows both a lamp resistance for large changes in speed and an adjustable wire resistance for smaller changes.

A blow on the spring B causes it to draw a sinusoidal line on the drum ; the waves, however, slowly decrease in amplitude, owing to loss of energy by friction. A quicker decrease, due to additional damping, can be ob-

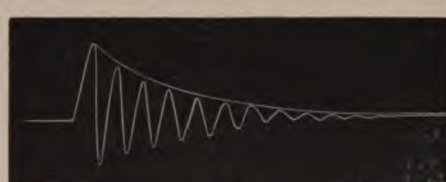

FIG. 12.

tained by placing the surface of the felt damper G more or less tightly against its edge. A curve of vibrations dying away by friction due to damping is shown in Fig. 12 ; it was made by the damped spring struck by a blow.

When a material point is displaced from the position of equilibrium to which it is attracted by a force that increases directly as its displacement,

and then released, its vibration can be expressed with close approximation by

$$y = a \cdot e^{-kt} \cdot \sin 2\pi \frac{t}{T},$$

where y is the displacement of the point at the moment t, a the amplitude, e the constant 2.71828, k a factor depending on the relation between the mass of the point and the amount of the friction, and T the period under the given circumstances. The amplitude a is subjected to a steady decrease by the divisor e^{kt}, for in the expression $a \cdot e^{-kt} = a/e^{kt}$ the amplitude will have its greatest value only when $k = 0$ or when there is no friction. Any friction will give a positive value to k and this will reduce the value of a. When there is friction the value of e^{kt} will increase proportionately as time elapses; thus a will be steadily reduced. The equation is illustrated by the curve in Fig. 12; the line drawn along the summits of the waves is the curve of amplitude $a \cdot e^{-kt}$.

A vibratory body may receive a series of impulses. The results of different natural periods of the vibratory point, of frictional factors, of

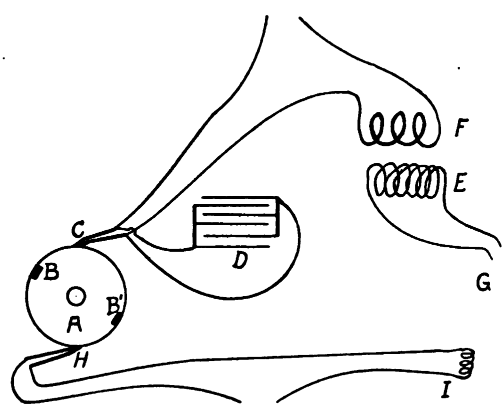

FIG. 13.

various strengths of impulse and of different intervals of repetition, can be studied by means of the vibrating spring. A series of impulses may be imparted to the spring B (Fig. 10) by brief electric currents sent through the magnet M. In a study of the action of such impulses on a spring these impulses were obtained and recorded in the following way. A hard rubber contact wheel A (Fig. 13) carried on its rim two pieces of metal BB'. A pair of copper brushes H bearing against the rim were the poles of a circuit through the magnet M (Fig. 10), indicated by I in

Fig. 13. As B or B' passed across H, it closed the circuit and sent a magnetic impulse to the spring. This had the effect of a sharp blow. The strength of the blow could be readily adjusted by varying the current or displacing the magnet M. As it was desirable to have an indication of the exact moment at which the impulse was sent to the spring, a spark coil was made to register directly on the line drawn by the vibrating point. A pair of copper brushes C formed the poles of a circuit through the primary coil F of a spark coil, whose secondary coil E was connected by the wires G to the metallic spring and the base of the recording drum. A condenser D was connected around the break at C. Whenever a metal piece B or B' passed under the brushes C, the circuit was closed. With an appropriate adjustment of the current, a spark passed from the recording point through the paper to the drum, removing the smoke and making a white dot when the circuit was closed and also when it was broken. The two pairs of brushes were so adjusted that the sparks registered exactly the moments at which the impulses were sent through the magnet and those at which they ceased.

A record of an experiment in which the contact wheel was revolved with steadily increasing rapidity is reproduced in Fig. 14. The waves were drawn by the point N (Fig. 10); the pairs of dots marked the

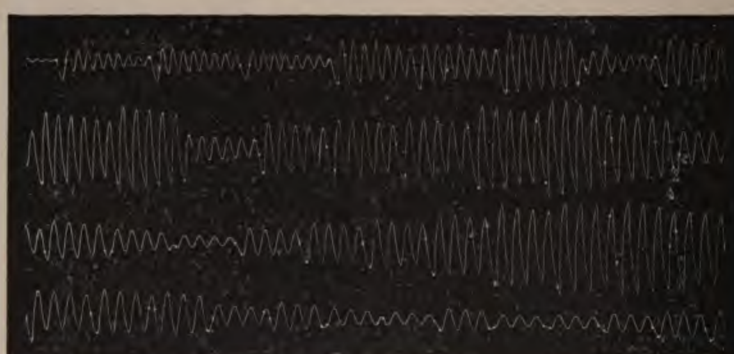

FIG. 14.

beginning and end of each impulse. The figure shows that each impulse started a vibration which died away by friction. If one impulse followed the preceding one before the vibration was entirely gone, its effect was increased or diminished according as the phase of movement in which it occurred was the same as or opposed to the movement started by the impulse. When the impulses occurred quite close together and at exactly the right phases, the summation of effects made the vibra-

tions very strong. In all such cases an increase occurred in amplitude whenever the period τ of the impulses became a multiple of the natural period T of the spring. In all cases the spring vibrated with the period T; only the amplitude was affected by the vibrations of τ.

The condition of equal lengths of impulse could not be illustrated with the arrangement just described, as the contacts through B and B' (Fig. 13) lasted a constant fraction of a revolution and the length of the impulse decreased proportionately as the speed of revolution increased. The impulses were weaker as they came faster. Nevertheless the increase in amplitude whenever τ was a multiple of T appears strikingly in Fig. 14. This increase in amplitude for harmonic relations (that is, according to the simple ratios 1 : 2 : 3 : etc.) between the natural period and that of the impressed force is known as 'resonance.'

A synthesis of two frictional sinusoids may be accomplished by the arrangement shown in Fig. 15. The spring B is the spring B of Fig. 10. Upon it there is placed the slide V carrying the spring U and another slide R with the electro-magnet S. The movement of B is recorded on a smoked drum by the point N, that of U by the point T. The magnet M of the spring B (Fig. 10) and S of the spring U (Fig. 15) are connected with the contact wheel A (Fig. 13). When the current passes through M alone, both points N and T draw the curve of vibration for B as in Fig. 14. When sent through S alone, the point T draws the curve of vibration of U. In both cases the vibration is a free frictional sinusoid. When the current is sent through both M and S, the point T draws the curve of the sum of the vibrations of B and U. The relations

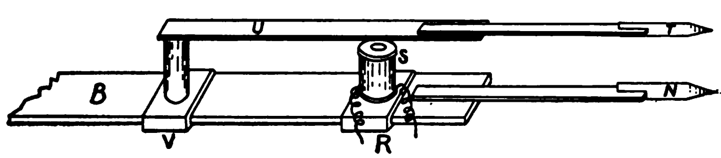

FIG. 15.

of period may be altered by changing the lengths of B and V, those of amplitude by shifting the magnets, those of damping by adjusting the dampers. When the curve drawn by T is like that found in a speech curve, it can be assumed that the speech curve is the result of two vibratory movements simultaneously aroused by a sudden blow, which have relations of pitch, amplitude and damping like those in the springs. The sudden blow is the puff from the cords heard in the cord tone and the two free vibrations are those of the vocal resonance cavities. Tables of typical combinations would be useful. A third sinusoid might be added

Ordinary breaths followed by several deep ones are shown in the top-most records; it will be noticed that the movements are very small after the blood has been refreshed by deep breathing. A record of ordinary breathing interrupted by sniffing, sobs and a sigh-like sob are shown in the second record; the inspirations are very sudden. The curves for a groan and a sigh are also shown in the third record; the inspirations are not sudden, and the expirations are more gradual than in the sigh, the groan showing a specially long and irregular expiration. All these sobs, groans and sighs were produced premeditatedly. A series of premeditated laughs is also shown. Each laugh consisted of 'ho-ho-ho-ho' with falling pitch; the laugh occupied the expiration-half of each curve. The record marked '4 lines of song' shows the breath expenditure during the singing of

"Way down upon the Swanee River,
Far, far from home;
Oh, darkies, how my heart does quiver,
Far from the old folks at home."

The expiration of the breath not used during each line appears clearly each time at the end. The next to last record shows the use of the breath in speaking the verses

"The Cities are full of pride,
Challenging each to each;
This from her mountain-side,
That from her burthened beach" (KIPLING).

The inspiration occurred just before the beginning of each line. The

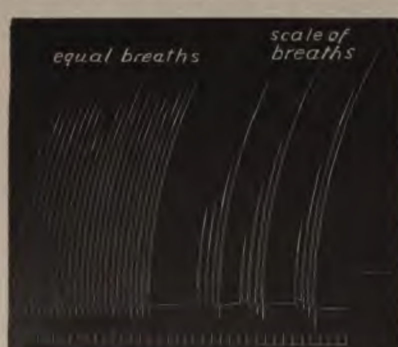

FIG. 17.

last record shows the breath-expenditure when the stanza was spoken more rapidly; one deep inspiration with a slight accession afterwards is

made to do for each pair of lines. The discharge of the air not used in speaking is indicated by the sudden rise at the end of each line. Both records were made with no intentional distribution of the inspirations. The time-line with seconds is given for all these records at the bottom.

Records of the air-pressure at the mouth were made by putting the end of a rubber tube loosely in the corner of the mouth and attaching the

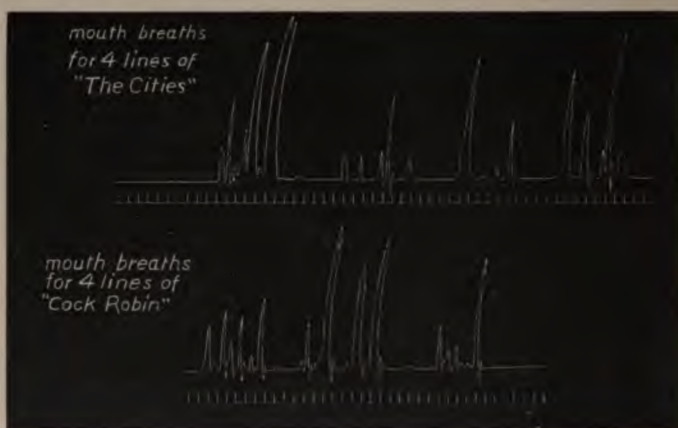

FIG. 18.

other end to a tambour recording on a smoked drum. Records of pressure intended to be equal and of some intended to be in the relations of 1 : 2 : 3 : 4 in intensity are shown in Fig. 17. Records of the variations in mouth-pressure during the recitation of four lines of KIPLING'S "The Cities," and of four lines of the nursery rhyme "Cock Robin," are shown in Fig. 18.

EXPERIMENTS ON MOTOR EDUCATION

BY

W. SMYTHE JOHNSON.

This series of experiments was instituted to determine the effects of light gymnastic exercise on quickness of voluntary movements and the development of the power of concentration of attention. It has been generally accepted that the direct effect of physical training is the development of strong and sinewy muscles and that mental quickening is only an indirect result of such training. The experience of the Elmira Reformatory showed that physical training has an educative value. By a graduated system in physical culture, the inmates who constantly failed in the School of Letters, in the Trades School and in deportment, were enabled to return and maintain their places in the regular institutional life.[1]

The experiments[2] carried out in this laboratory, during the academic years 1898–1900, by W. W. DAVIS and myself, showed conclusively that the effect of practice in speed and accuracy of voluntary movements was not limited to the member which was exercised, that the gain was principally conditioned by the power to concentrate attention, that the approximate highest rate of speed and the least variation in consecutive movements would be reached in from six to ten days with short practice each day, that the greatest gains were made during the first three days. It was also observed that those who developed most rapidly were those who took more or less gymnastic exercise.

In the following experiments the subject was seated in a quiet room, separate from the experimenting room. He was required to react to a sound coming from a click in a telephone. When all was ready for the record, a signal was sent into the quiet room by means of a telegraph-sounder. The subject understood that in one to three seconds after this signal he would hear a click in the telephone, to which he was to respond as quickly as possible by pressing on a telegraph key. Two degrees of intensity were selected, the subject knowing which would be used. The time was recorded on a pendulum chronoscope.

[1] SCRIPTURE, *Cross-education*, Pop. Sci. Monthly, 1900 LVI 589.

[2] DAVIS, *Researches in cross-education*, Stud. Yale Psych. Lab., 1898 VI 6.

JOHNSON, *Researches in practice and habit*, Stud. Yale Psych. Lab., 1898 VI 51.

First series of experiments.

The subjects were students in the Graduate School of Yale University, with ages ranging from 23 to 26 years. Subjects *A* and *D* were of a phlegmatic temperament; *B* and *C*, of a nervous temperament. All were in good health; they had not previously been taking any systematic exercise.

For each of the four subjects included in this test, ten records with the loud and weak sounds were taken at each sitting. After three sittings on successive days, they were then given pairs of six-pound dumbbells, and requested to practice with them for a few minutes during different intervals of the day; more especially just before retiring at night and on rising in the morning. The average daily practice for each of the four subjects was 45 minutes. They were not informed of the object of the practice with the dumbbells. After they had practiced for approximately two weeks, they were then subjected to another series of three tests in reacting exactly like the first.

The results (Table I) show a shortening of the average reaction-time ranging from 17^σ to 84^σ. In order to make clear the meaning of the figures given in Table I, I will explain those for subject *A* in detail. The figures 285^σ, 262^σ, and 221^σ are each the average of ten records, and denote the average time that it required to respond to the signal at each successive sitting. The average time of the first three sittings, 242^σ, is the average of the sum total of the records taken during the first three sittings. The average probable error was derived in like manner.

The average of the records taken after the practice with the dumbbells was 192^σ, thus showing a gain of 50^σ. But the gain for the weak sound shows more favorable results still, namely, 84^σ. The results for *A* clearly demonstrate the influence of systematic muscular training on the development of a sensitiveness to auditory stimuli. This subject being a little hard of hearing, his reactions to the weak sound were extremely slow previous to the practice with the dumbbells; but after the practice his responses to the weak sound were almost as quick as for the loud sound.

The table also shows regularly a decrease in the probable error.

It is evident that the regularity with which one responds to a given signal will depend upon how closely the attention is fixed on the action to be performed at each successive response. Hence the probable error of the ten records made at each sitting is a clear index of the subject's power to hold his attention during the performance of ten successive responses to a signal. If he allows the attention to be distracted by wandering thoughts, then the probable error will be increased.

The probable error, however, may depend on any one or more of the following causes: (a) fluctuations of attention, (b) actual increase in speed during the progress of an experiment, (c) fatigue of the nervous system. That the probable error given in Table I for all the subjects is due to (a), or lack of power to concentrate attention only, is evident for two reasons: (1) the time required for the experiment was too short to fatigue the system, and (2) the individual records show that there was no tendency to either increase or decrease of the reaction-time during the progress of an experiment.

TABLE I.

		Reaction to loud sound.						*Reaction to weak sound.*					
ubject.	Date.	Daily ave.	Ave. of three days.	Decr. after interval.	Daily p. e.	P.e. of three days.	Decr. after interval.	Daily ave.	Ave. of three days.	Decr. after interval.	Daily p. e.	P.e.of three days.	Decr. after interval
A	Jan. 22	285			37			320			44		
	" 23	262			43			308			45		
	" 25	221	242		31	33		257	282		40	42	
	Feb. 8	184			13			185			18		
	" 9	183			22			193			27		
	" 10	209	192	50	23	22	11	217	198	84	29	26	16
B	Jan. 20	210			19			215			24		
	" 22	216			24			248			19		
	" 23	251	225		29	25		243	235		30	26	
	Feb. 8	213			11			222			20		
	" 9	206			17			212			7		
	" 10	207	208	17	17	11	14	200	211	24	9	15	11
C	Jan. 22	278			63			234			29		
	" 23	247			25			225			16		
	" 25	180	234		15	48		173	204		10	31	
	Feb. 8	183			8			183			10		
	" 9	188			9			179			7		
	" 10	193	188	46	9	9	39	192	185	19	6	9	22
D	Jan. 18	289			45			302			45		
	" 19	218			25			227			51		
	" 20	189	232		29	29		191	240		29	44	
	Feb. 8	224			21			231			31		
	" 9	192			17			221			21		
	" 10	196	207	25	18	20	9	214	222	18	22	24	20

The unit of measurement is $1^{\sigma} = 0.001^{s}$.
Each figure under *Daily ave.* is the average of 10 measurements.
Each figure under *Ave. of three days* is the average of 30 measurements.
P. e., probable error.

Unlike such voluntary movements as the continuous tapping on a telegraph key, where the regularity of the tapping is proportionate to the development of subconscious control, in this form of action the reverse is true. It depends upon the power to hold the attention on the expected stimulus and the action to be performed.

A response to a sensory stimulus was the simplest form of action to be devised to test the influence of physical culture on the above-mentioned mental attributes, and was withal the most accurate test. The beneficial effects of the dumbbell exercise on the development of the power of concentration of the attention are clearly shown in the large decrease of the probable error in the experiments made after the practice with the dumbbells, varying from 9^{σ} to 39^{σ}. For instance, the average probable error for *C* previous to dumbbell practice was 48^{σ} and afterwards only 9^{σ}, thus showing a net gain of 39^{σ} in regularity of response to the sound in the telephone. This means, I believe, that the power of holding the attention was better developed in the latter part of the series of experiments.

Second series of experiments.

The subjects included in this series were juniors in the Academical Department. They were, at the time of the taking of the records, studying the question of movements in a course in experimental psychology. The four subjects were *E* (27 years of age, phlegmatic temperament, fair health, no gymnastic exercise), *F* (30 years, nervous, poor health, no exercise), *G* (24 years, phlegmatic, good health, no exercise) and *H* (22 years, nervous, good health, some exercise).

The subjects, instead of practicing with the dumbbells, were requested to spend some time each day in picturing as vividly as possible the processes involved in responding to the sensory stimulus.

The same apparatus was used and the conditions of experimentation were the same in this series as in the first. The subjects were each given three sittings on successive days. At each sitting ten records were made with the loud sound and ten with the weak one. After these records were taken the object of the experiment was explained to them, and they were asked to think about the matter for two weeks, after which they would be called in for another series of records. The experimenter made it convenient to speak with them on several different occasions during the interval between the taking of the records. Moreover, they were given some reading matter on the subject of reaction-time. The average time spent in reflection and reading on the subject was 35 minutes each day, varying, however, with each of the subjects.

The results given in Table II show considerable decrease in the re-

TABLE II.

Subject.	Date.	Reaction to loud sound. Daily ave.	Ave. of three days.	Decr. after interval.	Daily p. e.	P. e. of three days.	Decr. after interval.	Reaction to weak sound. Daily ave.	Ave. of three days.	Decr. after interval.	Daily p. e.	P. e. of three days.	Decr. after interval.
E	Feb. 20	252			26			248			15		
	" 21	256			15			271			22		
	" 22	224	244		14	20		224	248		16	21	
	March 12	197			11			196			12		
	" 13	190			11			183			7		
	" 14	200	195	49	11	11	19	218	199	49	12	13	8
F	Feb. 20	256			36			238			18		
	" 21	245			26			252			15		
	" 22	225	242		22	31		200	230		18	22	
	March 13	195			19			212			17		
	" 14	206			17			219			18		
	" 15	202	201	41	17	17	4	215	216	14	17	17	5
G	Feb. 20	286			33			262			30		
	" 21	260			29			254			14		
	" 22	236	254		19	23		248	255		16	21	
	March 13	240			20			228			14		
	" 15	210			22			218			15		
	" 16	214	221	33	31	23	0	218	221	34	23	17	4
H	Feb. 20	337			26			358			35		
	" 22	320			27			310			29		
	" 23	246	298		16	35		220	296		13	45	
	March 13	195			25			215			18		
	" 14	217			27			198			28		
	" 15	216	209	89	21	24	11	214	209	87	15	21	24

The unit of measurement is $1^{\sigma} = 0.001^{s}$.
Each figure under *Daily ave.* is the average of 10 measurements.
Each figure under *Ave. of three days* is the average of 30 measurements.
P. e., probable error.

action-time, even exceeding in amount that given in Table I. But the reaction-time for the subjects included in Table II was much slower at the beginning of the series than for those included in Table I. Even though the gain in reaction-time was greater for Series II, it does not signify that the proportionate gain was greater, for the reaction-times at first were much longer. That the gain in reaction-time for Series II was largely due to a special effort is shown in the comparatively small decrease of the probable error.

Subjects *E* and *H* each took much interest in the work; and from the remarks made, I am persuaded that the large decrease in their reac-

tion-time was largely due to the special effort put forth. In fact, all four of the subjects included in this series had the advantage of knowing the purpose of the test; this no doubt had its influence in calling forth a greater effort on their part than for those included in Series I and III. This is especially true of subjects *E* and *H*. But with even this additional incentive, when we take them by classes, we find that those of Series I were not only quicker than those of Series II in responding to the signal after the interruption of two weeks, but the probable error was also less.

Third series of experiments.

The conditions of experimenting were the same as in Series I and II, except that during the interval of two weeks elapsing between the third and fourth sittings nothing was required of them. In fact, they did not know that they would be called in for another test after the first series were over.

The subjects were students in the Graduate School: *I* (28 years of

TABLE III.

		Reaction to loud sound.						*Reaction to weak sound.*					
Subject.	Date.	Daily ave.	Ave. of three days.	Decr. after interval.	Daily p. e.	P. e. of three days.	Decr. after interval.	Daily ave.	Ave. of three days.	Decr. after interval.	Daily p. e.	P. e. of three days.	Decr. after interval.
I	Feb. 21	230			34			218			22		
	" 22	190			12			208			18		
	" 23	213	211		10	23		209	212		18	19	
	March 13	193			8			202			20		
	" 14	229			24			248			15		
	" 15	213	211	0	13	19	4	224	224	—12	15	20	—1
J	March 5	331			31			363			48		
	" 6	256			19			258			19		
	" 8	223	270		13	29		242	270		22	31	
	" 14	212			11			238			18		
	" 15	244			19			225			13		
	" 16	234	230	40	27	19	10	232	232	38	27	19	12
K	Feb. 21	293			32			318			34		
	" 22	293			38			266			28		
	" 23	258	281		36	36		259	281		34	35	
	March 13	229			27			243			21		
	" 14	234			21			229			21		
	" 15	211	225	56	23	23	13	207	226	55	12	21	14

The unit of measurement is $1^\sigma = 0.001^s$.

Each figure under *Daily ave.* is the average of 10 measurements.

Each figure under *Ave. of three days* is the average of 30 measurements.

P. e., probable error.

age, phlegmatic temperament, good health, athlete), *J* (36 years, phlegmatic, good health, outdoor exercise), *K* (25 years, nervous, good health, no exercise).

The results of this series of experiments are given in Table III. They show comparatively small gains both in reaction-time and in decrease of the probable error. The records of subject *I* show a reverse of what might be expected, for the reaction-time was actually longer and the probable error was larger after the intermission of two weeks than before it. He had played on the football team all the fall, and that possibly accounted for the quick reaction-time at the first three sittings. His first three tests plainly indicate the effects of previous training, for his responses were much quicker and much more regular than for any of the other subjects tested. He was the only athlete included in Series I, II, and III. The increase in reaction-time and decrease of regularity for *I*, after the intermission of two weeks, may have been due to the fact that during this time he had not taken any special training, having given up the gymnastic exercise just prior to the first series of tests.

Comparison of Series I, II, and III.

The average results of each group of subjects are given in Table IV.

TABLE IV.

	Average.			*Probable error.*		
	Series I.	Series II.	Series III.	Series I.	Series II.	Series III.
Loud sound, before	233	259	254	34	27	33
Loud sound, after	199	207	222	16	19	20
Decrease	34	52	32	18	8	13
Weak sound, before	240	257	255	35	27	35
Weak sound, after	204	211	227	18	18	20
Decrease	36	46	28	17	9	15

In regard to the average reaction-time there is a decrease for Series I (exercise) and II (thinking) as compared with Series III. In regard to the probable error no such relation is observed. Although the number of subjects was very limited, it seems reasonable to conclude that exercise and "thinking" increase the rapidity of response.

The average results of each group for each sitting are shown for the loud sound in Fig. 1, for the weak sound in Fig. 2, and the average probable errors in Figs. 3 and 4. The numbers on the horizontal axis indicate the days of the experiment; on days 1, 2, 3 the first records were made; then followed the interval, and on the 17th, 18th and 19th days the final records were taken.

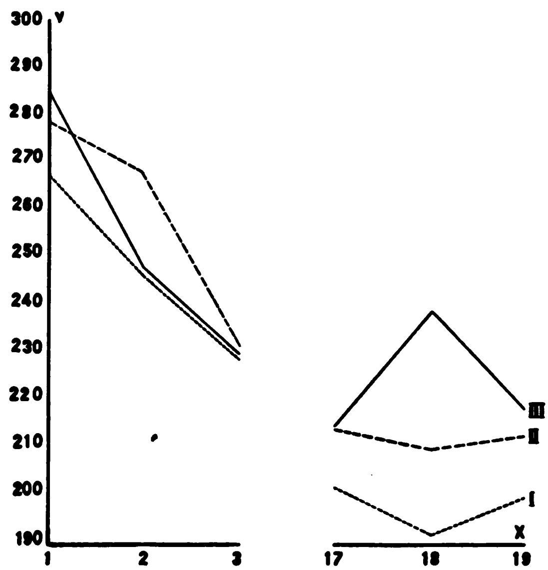
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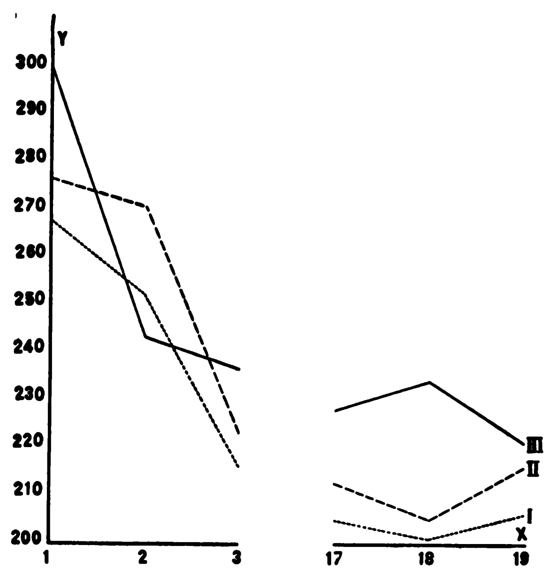
FIG. 1.


Y
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X
III
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19

FIG. 2.

The curves show in all cases a steady decrease in the average and the probable error during the first three days. On the 17th day the records are all somewhat smaller than on the 3d day, indicating perhaps some

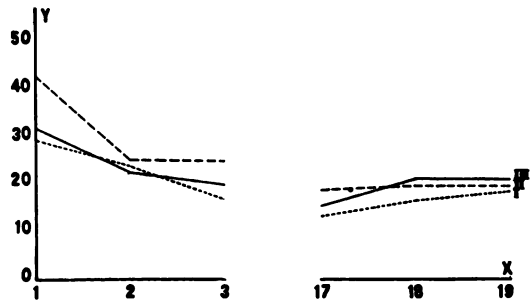

FIG. 3.

decrease due to persistence of impressions from the first experiments. If this same phenomenon should be observed in more extended experiments, it would point to active processes remaining after the reaction had been made.

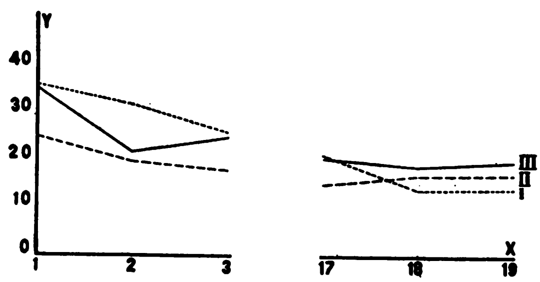

FIG. 4.

Fourth series of experiments.

A comparison was attempted between men who did not take any systematic exercise and those who were athletes at the height of training. The groups were made up as follows:

Group I.

Britan, age 25, weight 160 lbs., slightly nervous temperament, health robust, graduate student in philosophy.

Alexander, age 34, weight 155 lbs., very nervous temperament, health medium, graduate student in the Divinity School.

Cleland, age 28, weight 135 lbs., phlegmatic temperament, health medium, graduate student in geology.

Matsumoto, age 35, weight 145 lbs., phlegmatic temperament, health good, assistant in the Psychological Laboratory.

Geiser, age 30, weight 135 lbs., nervous temperament, health good, assistant in history.

Taylor, age 32, weight 145 lbs., phlegmatic temperament, health good, fellow in philosophy.

Mitchell, age 25, weight 183 lbs., phlegmatic temperament, health good, assistant in history.

White, age 30, weight 155 lbs., extreme nervous type, health good, graduate student in the Divinity School.

McAllister, age 30, weight 148 lbs., nervous temperament, health medium, fellow in psychology.

Sincerbeaux, age 25, weight 160 lbs., phlegmatic temperament, health medium, student in the Academic Department.

Group II.

Johnson, age 22, weight 135 lbs., nervous temperament, health good, captain of track team; specialty, pole-vaulting.

Richards, age 20, weight 138 lbs., very nervous temperament, health good; specialty, sprinting.

Fincke, age 22, weight 153 lbs., medium temperament, health good; specialty, hurdling.

Boardman, age 20, weight 152 lbs., slightly phlegmatic temperament, health good; specialty, sprinting.

Hord, age 21, weight 125 lbs., nervous temperament, health good; specialty, pole-vaulting.

Thomas, age 21, weight 154 lbs., nervous temperament, health good; specialty, hurdling.

Barnard, age 21, weight 155 lbs., nervous temperament, health good; specialty, hurdling.

Adriance, age 22, weight 130 lbs., nervous temperament, health good; specialty, pole-vaulting.

The first experiment made on each subject comprised ten records of a complex reaction. After the usual warning a red or a white cord was exposed in the pendulum chronoscope and the subject pressed the key if it was red, refraining if it was white. The reaction thus included discrimination and choice.

This experiment was followed by a series of twenty records in reacting to a loud sound in a telephone. The sound in the telephone was made very strong, in order to produce something of the shock of a starter's pistol.

Finally a series of ten records was made on the complex reaction-time just as in the first experiment. Before taking the second series, each subject was allowed to inspect his previous record and those of other persons.

The experimenter explained to each of the subjects that this was a test of his ability and that it would be compared with other records.

The reason for dividing the records in choice-time into two series was to overcome fatigue, to show the influence of practice, also to note the effect that a knowledge of one's previous record, as well as the records of others, would have upon the choice-time.

TABLE V.

Subject.	*A*	*p. e.*	*a*	*b*	*B*	*p. e.*	*a*	*b*	*C*	*p. e.*
					Group I.					
Britan	274	53	3	2	261	37	1	4	225	35
Alexander	242	33	5	1	252	26	2	2	194	19
Cleland	316	30	2	0	271	34	0	0	223	23
Matsumoto	301	45	2	3	277	33	0	1	192	21
Geiser	349	23	2	0	352	23	0	0	244	37
Taylor	328	30	4	0	260	50	1	1	223	27
Mitchell	349	55	3	0	369	35	1	0	252	35
White	297	58	3	0	312	30	3	4	156	21
McAllister	314	24	2	1	304	19	1	0	242	19
Sincerbeaux	303	28	1	2	291	30	0	0	224	19
Average	307	38	2.7	0.9	297	32	0.9	1.2	278	26
					Group II.					
Johnson	252	44	3	0	197	21	2	1	121	9
Richards	181	30	2	1					127	13
Barnard	209	30	3	1	243	33	4	0	129	17
Adriance	257	28	1	0	209	23	2	2	147	13
Boardman	219	43	3	0					171	14
Fincke	260	20	3	0	230	25	1	0	154	12
Thomas	284	33	1	0					165	17
Hord	171	31	3	1	220	19	2	0	160	18
Average	242	32	2.4	0.4	220	24	2.2	0.6	147	14
Difference, I–II	65	6	0.3	0.5	77	8	1.3	0.6	131	12

Group I, those without physical training.
Group II, athletes: sprinters, hurdlers, and pole-vaulters.
A, complex reaction-time, first experiment, ave. of ten records.
B, complex reaction-time, second experiment, ave. of ten records.
C, simple reaction to sound, ave. of twenty records.
a, number of times of false reaction.
b, number of failures to react.
p. e., probable error.
The unit of measurement is $1\sigma = 0.001^s$.

The differences show most clearly the superiority of the trained athlete over the untrained man in the time of both complex and simple reactions

and the special superiority in the latter. There is hardly any proportionate increase in regularity. There seem to be indications of increased control in the small number of mistakes made by the athletes.

A comparison of the *B* records with the *A* records indicates a decided influence of a knowledge of the previous experiments and of the fact that others had done better.

INVOLUNTARY MOVEMENTS OF THE TONGUE

BY

H. C. COURTEN.

Among the many psychological problems as yet only partially solved is that of automatic muscular movement. This is a phenomenon of many different phases, but the most important one, perhaps, is that of automatic movement of the speech organs. So far but little has been done toward its experimental demonstration. HANSEN and LEHMANN [1] satisfied themselves of its existence, but obtained no measurements in regard to it. CURTIS [2] secured some records showing unconscious movements of the larynx during mental action. These seem to be the only direct investigations of this problem.

The apparatus used in my experiments consisted of a ROUSSELOT [3] exploratory bulb (Fig. 1) fitted with a long tube connected to a MAREY

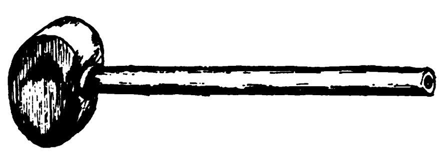

FIG. 1.

tambour. The bulb was of French make, about 1 cm. in thickness (measured in the direction of the tube), and 9 sq. cm. in cross section. This size was decided on only after repeated trials with bulbs of different sizes. The records were made on a kymograph.

Some difficulty was experienced in finding the correct position for the bulb. At first it was placed far back in the mouth near the palate, because it was thought that the greatest movement of the tongue would be manifested there. But while it was in this position the subject showed a tendency to gag, and could not hold the bulb quietly in place. The most convenient and effective position was finally found to be in the front part

[1] HANSEN UND LEHMANN, *Über unwillkürliches Flüstern*, Philos. Stud., 1895 XI 471.

[2] CURTIS, *Automatic movements of the larynx*, Amer. Jour. Psychol., 1899 XI 237.

[3] ROUSSELOT, Principes de Phonétique Expérimentale, 86, Paris 1897.

of the mouth between the teeth and the tip of the tongue. Thus the tongue was in a fairly natural position, and the slightest movement was recorded. The bulb was entirely unaffected, in this position, either by pulse or by respiration.

The subject was required to do several kinds of mental work without speaking, such as reading prose and poetry, thinking out the etymological relations of various English words ('exhortation,' 'advocation,' etc.), reading Scotch dialect, French, or German, reciting the alphabet, committing verse to memory, etc.

The subject was seated in a chair with his back to the instrument and the bulb carefully adjusted in his mouth. The kymograph was then set in motion and the subject was asked to keep his mind as free from thought as possible. After a short tracing had been secured during mental rest, the subject was told to perform some of the tests mentioned above. In all nine experiments were made. The accompanying figures give typical results.

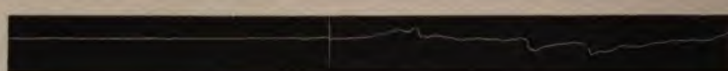

FIG. 2.

The first part of the tracing in Fig. 2, as far as the dividing mark, was made during a period of mental rest; the second part, during the reading of English prose.

FIG. 3.

Fig. 3 shows a record made after the subject had been requested to remain as free from thought as possible; but after the record had been made he confessed that he had, unintentionally, been thinking of the experiment. The record is significant inasmuch as it shows that movements do occur, in consequence of mental action, without the knowledge of the individual.

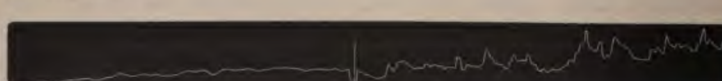

FIG. 4.

Fig. 4 shows the results of a second experiment with the same subject as for Fig. 3. In this case, as the relatively straight portion of the trac-

ing seems to show, the subject was successful in suppressing thought. The test producing the undulations consisted in committing verse to memory.

FIG. 5.

The tracing in Fig. 5 shows the physiological effects of reading French, and that in Fig. 6, of reading English. The difference was intensified

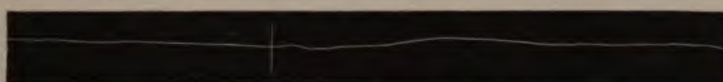

FIG. 6.

by the fact that the English selection was totally devoid of emotional passages.

FIG. 7.

Fig. 7 shows a record made while the subject was mentally reciting the alphabet.

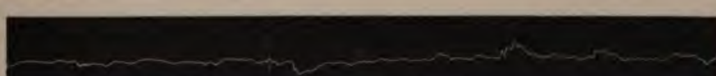

FIG. 8.

Fig. 8 shows a record made while reading German.

The subjects of this set of experiments were a mechanic, two sophomores, three freshmen, a junior and a professor of Yale College. It is not to be understood from the above figures that all tracings showed an equal degree of movement. It can be said, however, that no record was taken which did not show some movement. It was noticed that the tongue was more strongly influenced during intense thought than during less active thinking, and that reading a dialect, or language unfamiliar to the subject, produced a greater effect than the reading of English. But regardless of all variations in the results obtained, the fact was established that unconscious movements of the tongue do take place during mental action.

PHONETIC NOTATION

BY

E. H. TUTTLE.

I. GENERAL PRINCIPLES.

In order to discuss speech sounds in a concise and intelligible manner, we must represent them by signs of fairly definite meaning. Ordinary orthography will not do for this purpose, since in nearly every language there is more or less of irregularity in the relation of spoken words to their written forms. Thus, in English, groups of letters are often used for simple sounds, and conversely; 'rough' = 'ruff,' 'sword' = 'soared,' 'phlox' = 'flocks.' In German 'wird' = 'wirt(h),' 'stadt' = 'statt,' 'viel' = 'fiel,' 'feld' = 'fällt,' 'so(o)le' = 'sohle,' —z rimes with —ds, —ts, etc. In French 'car' = 'quart,' 'sans' = 'sang' = 'sens' = 'sent' = 'cent,' 'saoul' = 'sous' = 'soue,' 'ceins' = 'ceint' = 'cinq' = 'sain' = 'saint' = 'sein' = 'seing,' 'souhait' = 'soi.' In Italian half the letters of the alphabet are used in two or more different manners.

It is evident that we need for scientific purposes a sign system free from such serious faults as these. It should, however, be kept in mind that to construct and employ a mathematically exact system would be practically impossible, because of the linguistic and physiological differences between individuals.[1] Many of the phonetic symbols used here must therefore be understood as representing *groups* of slightly different articulations, sounds or properties.[2]

One of the first points to be considered is how to distinguish phonetic letters from orthographic ones. Many writers, overlooking the importance of this consideration, make no distinction between orthographic and phonetic spelling, with the result that their work is sometimes unintelligible, or, worse yet, misleading. Thus, when a French writer speaks

[1] The formula system of representing sounds is evidently intended as an approach to mathematical accuracy, but can hardly be called a phonetic transcription in the proper sense of the term; it is rather a description in a sort of physiological shorthand. (JESPERSEN, Fonetik, Köbenhavn 1897–1899.)

[2] The fact that speech does not consist of a series of adjacent sounds independent of one another, as implied by an alphabetic representation, will be left out of account here.

of "*u* allemand" or "y anglais,"[1] we are more or less in the dark as to what he is talking about.

In some cases it may be found convenient to use phonetic and orthographic signs in combination; thus for instance in a discussion of stress or pitch, much space can be saved by writing "^{1}Ja^{0}pa^{2}nese" instead of "'Japanese' ^{1}*dʒæ*^{0}*pə*^{2}*niis*," where the particular vowels and consonants used are of no especial importance. But this freedom should not be extended too far; such mixtures as "*mamzel, vla, dja, syisi, membrə*,"[2] are highly objectionable, as they might seriously mislead a reader not perfectly familiar with the language represented.

As the scientific notation employed in this article contains roman[3] letters, it will be enclosed in brackets, to prevent confusion with orthography. The English textual system is in italics, which will permit dispensing with the [ ].

Another important point in phonetic work is consistency. This also has received none too much attention, even from the best writers. PASSY uses two different modifiers on the same page[4] to indicate syllabicness. ROUSSELOT uses "*h*" for the two quite distinct fricatives of German 'hage.'[5] ELLIS employs the sign (') in two apparently quite different ways: (') = [*ə*], and ('n) = syllabic or long [*n*];[6] another phonetician coming upon a text containing numerous (')'s, mistranscribes it[7] into an unpronounceable form containing syllabic *v*, *z*, etc. SWEET transcribes the Arabic dental fricatives sometimes by "ð þ" and sometimes by "*ð ϑ*," without apparent reason for this distinction.[8] STORM uses "*æ, ɛ, ę*" sometimes for the same vowel (that of 'air'), sometimes for different sounds.[9] HEMPL seems to use "f" and "v" with the same value.[10] SIEVERS employs "r^i" to mean *i*-modified *r*, "e^i" to mean *e* followed by nonsyllabic *i*, and "$^•$" to indicate a half-sonant *ə*.[11] There is a similar inconsistency in the use of superior letters in the system of JESPERSEN,[12] and in that of MURRAY.[13] We find one of the vowels

[1] ROUSSELOT, Principes de Phonétique Expérimentale, 157, 181, Paris 1897.
[2] STORM, Englische Philologie, 2te auflage, 187, Leipzig 1892.
[3] I use "roman" in contrast to italic; "Roman" in contrast to Greek, Russian, etc.
[4] PASSY, Sons du Français, 5^e édicion, 58, Paris 1899.
[5] ROUSSELOT, Principes de Phonétique Expérimentale, 410, 554, Paris 1901.
[6] ELLIS, Early English Pronunciation, 10, London 1869–1889.
[7] SIEVERS, Grundzüge der Phonetik, 4te auflage, 41, Leipzig 1893.
[8] SWEET, Practical Study of Languages, 31, 233, New York 1900.
[9] STORM, as before, IX, 56.
[10] HEMPL, German Orthography and Phonology, 156, xxx, Boston 1898.
[11] SIEVERS, Grundzüge der Phonetik, 5te auflage, 185, 180, 110, Leipzig 1901.
[12] JESPERSEN, Fonetik, 229, 515, Köbenhavn 1897–1899.
[13] MURRAY, New English Dictionary, vol. 1, p. xxv, Oxford 1888.

(a small "O") that is defined as "short" in HAMILTON's notation used with the length-modifier, and a vowel ("ɑ") that is defined as "long" used for the short vowel of 'not.'[1] In PASSY's system the character "ɹ" is used in three entirely different ways: to indicate a consonant; to indicate qualitative modification of the preceding vowel; and to indicate both qualitative and quantitative modification.[2]

Of equal importance with typographical consistency is linguistic consistency. SWEET transcribes English "long e" as vowel + consonant, and then gives 'sea' as an illustration of a final long vowel.[3] After criticising SWEET for calling English ā and ō vowel diphthongs, but ē and oo vowel-consonant groups, SIEVERS transcribes 'YE' with a diphthong, and 'WOUND' with a simple long vowel.[4] HEMPL calls w in 'way' a consonant, but y in 'yet' a vowel,[5] although these sounds are really of the same general character. Some of the dictionaries[6] transcribe 'allow' with two *l*'s, although only one has been pronounced during the last ten or twelve centuries. Until very recently the American Dialect Society has used "*o* as in *not*" along with "*ô, ou* as in *no*" and "*oi* as in *coin*,"[7] notwithstanding the confusion that is liable to arise from such a system.[8]

Consistency in the physiological basis of a transcription is also very desirable. When we find a fricative defined as being similar to the Arabic and German glottal catch, and the sounds [*m*] and [*n*] called fricatives, while [*ɲ*] and [*ŋ*] are classed as occlusives,[9] we feel tempted to doubt the accuracy of certain other statements made by the same writer. The two Italian z-sounds are often described as simultaneous *t* and *s*, *d* and *z*,[10] although such a combination of stoppage and non-stoppage of the air-current is physically impossible. One well-known sound system divides the vowels according to the assumed tongue-positions into 'front,' 'mixed' and 'back,' and 'high,' 'mid' and 'low';

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[1] [HAMILTON,] *With the linguists*, Herald, April 1902 (Toronto), p. 90.

[2] *Exposé des principes de l'association phonétique internationale*, Supplément au Maître phonétique de novembre 1900 (Passy), p. 8, 12, 15, 18.

[3] SWEET, Primer of Phonetics, 21, 43, Oxford 1890.

[4] SIEVERS, as before, 163.

[5] HEMPL, as before, xxx, xxvii.

[6] [MARCH,] Standard Dictionary of the English Language (Funk), New York 1895. [BARNUM,] Webster's International Dictionary of the English Language (Porter), Springfield 1901.

[7] Dialect Notes, vol. i, p. 27, vol. ii, p. 190.

[8] Dialect Notes, vol. i, p. 233, 452.

[9] ARAUJO, Fonétika Kastellana, 24, 36, 37, Madrid 1894.

[10] D'OVIDIO UND MEYER, *Die Italienische Sprache*, Grundriss der Romanischen Philologie (Gröber), 1ter band, 491, Strassburg 1888.

ELLIS, as before, 800.

the last class is defined as having the lowest possible position of the tongue,[1] the results of such a definition being apparently overlooked. In pronouncing a 'low-front' vowel, where is the back of the tongue? It cannot be above 'high' nor below 'low'; it cannot be 'high' nor 'mid' (for either of these positions would produce 'back' vowel), and consequently must be 'low.' In other words 'low-front' is identical with 'low-back.' Further discussion is hardly needed to demonstrate the frailty of the whole system.

The legibility of phonetic characters is an important consideration. In one system we find "s" and "s" used for different sounds.[2] SWEET uses for [ɣ] and for [ʒ] two very similar signs[3] — so similar, in fact, as to be misprinted in one of his own books.[4] Frequently "*æ*" and "*æ*" are used in the same alphabet.[5] VIETOR transcribes two German sounds by "*j*" and "*j*."[6] PASSY employs "*g*" and "*ɡ*" for two sounds as nearly distinct as *s* and *t* in his so-called "international alphabet";[7] this, of course, makes difficult reading in texts where both signs are used.[8] LEPSIUS uses a "*t*" with a microscopic "*s*" beneath it in transcribing Slavic languages, because these happen to represent the sound group *ts* by a single letter.[9] ROUSSELOT often employs minute superscript letters as modifiers;[10] in the case of nasalized "*ȃ*" the tilde is so small that it might easily be mistaken for a macron or grave accent.[11] The more new types an alphabet has, the less easy will it be to read and to remember; this reason, as well as the one mentioned below, explains to a large extent the failure of new-type alphabets to come into common use. The illegibility of his organic alphabet in its script form has been admitted by SWEET himself;[12] for the ordinary educated person the printed characters are extremely hard to read.

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[1] SWEET, as before, 14.

[2] Century Cyclopedia of Names (Smith), vii, New York 1899.

[3] SWEET, as before, 97, 98.

[4] SWEET, Practical Study of Languages, 17, New York 1900.

[5] VIETOR, Élemente der Phonetik, 4te auflage, Leipzig 1898.
VIETOR, German Pronunciation, 2d edition, Leipzig 1890.
SIEVERS, Grundzüge der Phonetik, 5te auflage, Leipzig 1901.

[6] VIETOR, as before.

[7] Maître Phonétique (Passy), since 1894.

[8] VIETOR, Aussprache des Schriftdeutschen, 4te auflage, Leipzig 1898.
DJELALI, Contes et Chants Arméniens, Paris 1899.

[9] LEPSIUS, Standard Alphabet, 2d edition, London 1863.

[10] ROUSSELOT, Principes de Phonétique Expérimentale, 332, 614, Paris 1897-1901.

[11] ROUSSELOT, as before, 224.

[12] "As I had some difficulty in deciphering your postcard—which isn't *your* fault but the fault of visible speech which I'm afraid is quite unsuited for practical work—I write in Roman letters." SWEET, quoted by SPIESER, *lautfrift*, Maître Phonétique, 1895 X 139.

It is not sufficient that a system should not be difficult to read; it must not be unpleasant to read, if it is to be at all widely adopted.

In order to be pleasant to read, a textual alphabet should be as uniform as possible; a mixture like "iŋgli*ʃ* t*ʃ*aild" is highly objectionable, where the italics serve no phonetic purpose.[1] An exception to this principle may be made, however, where it is desirable to call attention to certain sounds. Thus in an italic text for English students it might be well to transcribe the Russian palatalized consonants or the French orinasal vowels by roman letters, or by heavy-face ones.

Compactness is also an important feature of an alphabet. The clumsiness of using several characters for a single sound becomes a serious waste of space in cases like "œœ"[2] for long [ɜ], and "p[ʰ]"[3] for English *p*. Practical experience has shown that it is best to indicate quantity, stress and pitch by separate modifiers; these signs should be as small as is compatible with legibility. In a scientific notation the use of modifiers may be considerably extended.

The employment of many diacritics should be avoided; a transcription with a mark over or under nearly every other letter, or with two and three marks on some, gives to the printed page a repellant aspect.[4] A single word like "*žü·žé*" (VIETOR's notation) = French 'jugeait' [ʒy·ʒɛ] will illustrate this fairly well. In the system of LEPSIUS, the second vowel of French 'emprunte' is written "*o̩*" with a straight line under it, another over it, a tilde over this, and an acute accent over the tilde; in ROUSSELOT's alphabet the corresponding sign is "*œ*" with a vertical line under it, a grave accent, a macron, and a tilde over it.

A fourth requirement is that, so far as possible, familiar letters should not be used in unfamiliar ways; a transcription like "psjφ"[5] for French 'monsieur' is very disagreeable to a person familiar with Greek. In English, where every letter is used in more than one way, any fixed use must be to some extent unfamiliar. For the vowels *a, æ, e, i, o, u, y,* we can hardly do better than return to the Old English values; the consonants should, of course, be used with their commoner or older sounds, except in the case of the superfluous ones (*c, j, q, x*).

A phonetic notation, to be suitable for general use, should be easy to print with types now in common use. Although PASSY has recently

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[1] SWEET, Practical Study of Languages, 17, New York 1900.

[2] SWEET, as before, 41.

[3] PASSY, Sons du Français, 5e édicion, 120, Paris 1899.

[4] VIANNA, Exposição da Pronuncia Normal Portuguesa, 99, Lisboa 1892.
VIETOR, German Pronunciation, 2d edition, 113, Leipzig 1890.

[5] SWEET, History of Language, 28, New York 1900.

denied the validity of this proposition,[1] he practically admits it by using in one of his most important books[2] his easily printed sonant-velar-fricative sign instead of the proper new character to represent the occlusive [*g*].

The casting of new types requires a considerable outlay of time and money, and consequently many writers, publishers and printers would refuse to have anything to do with a phonetic notation containing them. On this account the various new-type systems that have been constructed, including those now employed by BELL[3] and by SWEET,[4] seem to be total failures so far as general adoption is concerned. The numerous Roman-basis alphabets now used all seem to require a larger or smaller number of new types, and are therefore all equally unsuited for practical use; for the employment of a single specially cast character makes a system almost as difficult to use as would the employment of a hundred.

While it is highly desirable that new types should not be used, it is perhaps even more important not to waste old types that are readily available and suitable for phonetic purposes. In the systems of ELLIS and of LEPSIUS capitals are used as in orthography, without any phonetic significance; this greatly increases the number of new types in one, and of digraphs in the other, besides making the alphabets much more difficult to use. In one of the best of the dictionaries[5] we find the same sound represented in different ways: 'come' "cum," 'came' "kêm." Such inconsistencies are not permissible in a phonetic alphabet; a system containing them is really only a reformed spelling, not a phonetic one.

II. DETAILS.

a. Types used.

The most readily available types are of course those of the Roman alphabet: *a b c d e f g h i j k l m n o p q r s t u v w x y z*; the corresponding capitals may also be employed in a scientific notation: *A B C D E F G H I J K L M N O P Q R S T U V W X Y Z.* As small capitals are made only in roman, and as many of them are more or less similar to lower-case letters (C I J K O S U V W X Z), no use of them will be made here.

Of the "accents" commonly made for English fonts, the following are used: *à è* etc., *â ê* etc., *ë ï ö ü ç*; of the ligatures, *æ fi*; of the

[1] PASSY, *l ynite fɔnetist*, Maître Phonétique, 1901 XVI 106.

[2] MICHAELIS ET PASSY, Dictionnaire Phonétique de la Langue Française, Hannover 1897.

[3] BELL, Sounds and their Relations, Salem 1881.

[4] SWEET, Primer of Phonetics, Oxford 1890.

[5] [MARCH,] Standard, as before.

full-sized numerals, *2 3*; of the punctuation marks, , : . ' - ! † ‡ ||. The Danish alphabet furnishes two very serviceable types, *å* and *ø*, and Greek a large number: *β γ δ ε ζ η ϑ ι λ ξ ρ σ τ φ χ ψ ω* ̔ ̓ ` ^ ˘. These foreign types are in a few cases chosen arbitrarily; in most instances they are used with approximately their native values, or else are to be considered as modifications of similar Roman letters.

The number of available characters can be increased by means of different styles of type — as roman, heavy-face, superior, inferior — and by means of cut and turned letters. It should be noted that some types are not suitable for use in this last manner; turned b, d, n, p, q, s, u, x, z are rather hard to read. Turned o is indistinguishable from direct o, unless the alinement is very uneven; the use of the two together[1] makes a text practically illegible.

Cut types are of two sorts, face-cut and body-cut. The process of body-cutting is sometimes undertaken by printers in preference to ordering special characters from a foundry, such as š, accented æ, capital ç, etc. It is very objectionable not only by reason of the considerable time and expense involved, but because the cutting and adjusting are often poorly done, lying as they do outside of the typesetter's regular line of work. Face-cutting is a comparatively simple matter; it should not, however, be employed for any great number of signs. In the ***textual notation*** (English) of this article, only one face-cut type is needed, the length-sign ᵎ, made from an exclamation point. Certain kinds of face-cutting should not be undertaken without proper consideration of the other principles involved. Thus the use of dotless i or j may seem a very simple expedient; but to use "i" and "ı"[2] or "*j*" and "*ȷ*" in the same alphabet is a serious mistake, because in printing the dots are sometimes broken off, so that whenever the reader sees one of these types he is uncertain whether the mutilation is accidental or intentional.

b. Scientific notation.

A scientific notation should be so constructed as to be capable of providing a suitable transcription for any speech sound. An attempt will be made here to outline such a sign-system, due regard being paid to the principles considered in the preceding pages, and to the present usages of philologists.

One of the first things to be symbolized is the motion of the air-current. While the exact method of indicating this is not very important, it is

[1] ARAUJO, as before, 143.
[2] *Exposé* etc., as before, p. 14.

important to have *some* method, in order to avoid the confusion that is to be found in some writers.[1]

[||] respirate (current due to lung-action).

[‡] irrespirate (current not due to lung-action).

[†] ingressive (current passing into vocal organs from external air).

[⍖] egressive (current passing from vocal organs to external air).

Irrespirate and inspirate sounds are often used in interjections, as [‡†ʇ:], [||†*ye*⍖*s*]; otherwise ordinary speech is generally expirate in European languages. The modifiers [||] and [⍖] will therefore be usually understood, where the contrary is not indicated.

i. Consonants.[2]

LABIAL

BILABIAL

occlusive, [*b*; *p*] F. b; p.

corresponding orinasal, [*m*] E. m.

vibrant, [ʙ] in [*b*ʙ'] expressing a feeling of coldness.

fricative, [*β*; *φ*] Dutch w; Japanese f. The sign similar to *υ* used for [*β*] by Passy is quite objectionable, because it is a new type; also because in italics it must be printed as "*v*,"[3] the distinction between [*v*] and [*β*] thus being lost, or else the relation of "*υ*" and "v" must be just reversed, in "*ν*" and "*v*,"[4] in order not to disturb the universal association of *v* with v.

strictive, [*ω*] a rare substitute for E. *r*.

BILABIAL-MARGINAL

occlusive orinasal, [*ɱ*] [5] a common respiration-articulation with sonancy added; [*ɱ*'] = "yes."

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[1] Passy, Sons du Français, 5e édicion, 116, Paris 1899.

Rousselot, as before, 488.

[2] The terms "consonant" and "vowel" will be used here in the ordinary manner, without discussion of the hitherto undetermined distinction between the two classes. It is noteworthy that the consonants can in nearly all cases be referred to fairly definite genetic conditions, or articulations; while this is not easily done for the vowels, as is shown by the widely differing vowel-theories upheld by various writers.

Where two consonant-signs in the list are separated by a semicolon, the first is sonant, the second surd; where only one is given, it is sonant unless the contrary is stated. Articulations are oral unless stated to be orinasal.

The following language names are abbreviated to their initial letters: American English, British English, English, French, German, Hungarian, Italian.

[3] Maître Phonétique (Passy), 1897 XII 80, 81.

[4] Vietor, Aussprache des Schriftdeutschen, 4te auflage, 5, 17, Leipzig 1898.

[5] To be associated with *m*.

BILABIAL-DORSAL

strictive, [*w*] E. consonant w; approximately a combination of the labial [*ω*]-position and the lingual [*u*]-position.

LABIOBIDENTAL

surd fricative, [*ɸ*] in [‡†*pɸ*'] sometimes used to urge on horses.

LABIODENTAL

occlusive, [b; p].
corr. orinasal, [m].
fricative, [*v̀*; *f*] F., I. v; f.

DENTAL

fricative [*ϱ*; *ϱ̥*]; inspirate [*ϱ̥*'] is sometimes used as an interjection of pain.

LINGUAL[1]

marginal

INTERDENTAL

fricative, [*δ*; *ϑ*] E. sonant th; surd th. The signs "ð þ" for these sounds are in general use among Germanic philologists; the chief objection to them is that italic þ is very similar to certain styles of *p*, so that one is liable to be misprinted for the other.[2] Another important consideration is the fact that many printers, and even type-founders, have difficulty in furnishing italic ð þ.[3] If roman *δ ϑ* are needed, 9 might be used for the latter, while the former could be made by cutting 8; or ð might be considered the roman letter corresponding to italic *δ*. The German printers' crossed d, evidently intended as an improvement on ð, is unsuitable for practical use, being much inferior to it in legibility.[4]

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[1] Names of lateral articulations are in italics.

[2] Modern Language Notes, 1901 XVI 154 (c. 307).
EMERSON, History of the English Language, 235, New York 1897.

[3] SWEET, Practical Study of Languages, 135, 233, New York 1900.
SWEET, History of Language, 28, 125, 131, New York 1900.
SIEVERS, as before, 147.
EMERSON, as before, 241.
HEMPL, as before, xxvi, xxviii, xxix, 128.
American Journal of Philology (Gildersleeve), 1901 XXII 427, 430.

[4] Compare LLOYD'S Northern English (Leipzig 1899) with SWEET'S **Elementarbuch** des Gesprochenen Englisch (Oxford 1895).

POSTDENTAL

fricative, [*ɒ*; *σ*] sometimes distinguished in English, though perhaps never distinctive: [*sikσ'*] = [*siksϑs*] 'sixths'; [*hæzɒəm*] = [*hæzδəm*] 'has them.'

ALVEOLAR

occlusive, [*d*; *t*] E. d; t.
corr. orinasal, [*n*] E. n.
occlusive, [*ɗ*; *τ*]. Independent lateral occlusives are rare; [‡†τ'] or [‡†τ*ʒ*] is used to urge on horses. In words like 'wildly' and 'faultless' the occlusives are necessarily lateral, and do not need to be marked as such in an ordinary transcription.
vibrant, [*r*] Scotch r.
fricative, [*z*; *s*] E., F. z; E., F., G. "hard" s.
fricative, [*ζ*; *ʒ*]. Welsh ll = [*ʒ*]?
strictive, [*ɹ*] Londonese consonant r?
strictive, [*l*] G. l.

ALVEOLAR-DORSAL

strictive, [*ɫ*] E. l; a [*l*] with approximately [*ü*]-modification of the dorsal tongue position.

CEREBRAL

[d t n r z s ɹ l] differ from [*d t n r z s ɹ l*] in having the tongue point much farther back.

PAGINAL

fricative, [*ʒ*; *ʃ*] F. j, E. si in 'vision'; E. sh, F. ch, G. sch. These signs, now coming into common use, are preferable to the German philologists' ž š by reason of their greater legibility and ease of writing, and also because the Bohemian accented letters are difficult to obtain in this country. The chief objection to *ʃ* is its similarity to ordinary *f*; this may be avoided by using an italic f with no kern at the bottom. If a roman character is needed, the letter ſ might be used; the resemblance could be increased by removing one serif. The articulation of the paginals seems to be quite variable; the assumption that [*ʃ*] is necessarily formed farther back than [*s*] [1] is as incorrect as the older theory that [*ʃ*] is simply [s].[2]

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[1] SIEVERS, as before, 131.
[2] HENRY, Comparative Grammar of English and German, 27, London 1894.

d o r s a l

PREPALATAL

occlusive, [ɟ ; c][1] H. gy ; ty.
corr. orinasal, [ɲ] Italian gn, Spanish ñ.
fricative, [j ; ç] G. j g in 'jäger'; ch in 'mächte, bücher.'
fricative, [ʒ ; ʃ].
strictive, [j] E. y in 'year,' e in 'ewe, few.' This sound is about as distinct from [j] as [z] is from [ð] ; it is a serious mistake to use a single sign, as some writers do, for both sounds. The relation of [j] to the strictive [ɥ] of F. 'lui' seems to be the same as that of the vowels [i] and [y].
strictive, [ʎ] I. gl(i). PASSY's double use of italic ʎ,[2] sometimes for this sound, and sometimes for a *h*-sound, is objectionable ; ʎ might be used instead of ʎ, but the other form (ɦ) should not.

PALATOVELAR

occlusive, [*g* ; *k*] E. "hard" g ; k.
corr. orinasal, [ŋ] E. ng in 'young,' n in 'younger, uncle.'
fricative, [γ ; χ] G. g in 'lage' ; ch in 'macht, buch.' PASSY'S use of "g" for the sonant fricative[3] is extremely objectionable, because it involves, in a roman notation, the use of a new type for the sound [*g*], and because the letter g is in most European languages commonly associated with the occlusive. The unpractical character of PASSY's notation is shown by the fact that several books[4] represented as using it employ "g" as an occlusive, while one[5] uses "g" for [*g*] about twice as often as for [γ].

POSTVELAR

occlusive, [g ; k].
corr. orinasal, [ŋ].
vibrant, [ʀ] a common form of German r (uvular trill).
fricative, [q ; x]. A roman form more similar to γ could be made by cutting off half the loop of q.
strictive, [ɹ].
strictive, [ʟ] Russian "hard" l? The Polish crossed *l* (ł) often used for this sound is objectionable because it is not easy to obtain, even from type-foundries, and because it is easily misprinted as *t*.[6]

[1] To be associated with *j ç*.
[2] Maître Phonétique, 1897 XII 79, 1900 XV 66.
[3] PASSY, Sons du Français, 5e édicion, 111, Paris 1899.
[4] MICHAELIS ET PASSY, as before.
PASSY, Le Français Parlé, Leipzig 1897.
LLOYD, Northern English, Leipzig 1899.
SPIERS, Senior French Reciter, London 1902.
[5] RIPPMANN, Elements of Phonetics, 7, 14, 35, 40, 52, 57, 79, etc., London 1899.
[6] Maître Phonétique (Passy), 1893 VIII 100, 1902 XVII 1, 108.

LARYNGEAL

GLOTTAL

surd occlusive, [*ɂ*] G. "glottal catch."
surd fricative, [*h*] E. h, G. h.

Other sounds of this class seem to be distinguished in oriental languages; but until their articulations are better known, it is hardly necessary to provide signs for them.

ii. Vowels.[1]

NORMAL

[i] F. i, G. ie, I. i.
[*i*] G. open i.
[e] F. é, G. eh, I. close e.
[*e*] G. e in 'feld,' ä in 'fällt.'
[ɛ] F. è, ê, G. äh, I. open e.
[*æ*] E. a in 'pats,' A. a in 'past.'
[a] F. a in 'part, page, patte.'
[*a*] I. a.
[ɑ] F. â.
[*ȧ*] E. au, aw.
[*ɔ*][2] I. open o.
[*o*] G. o in 'sollte, sonne.'
[o] F. eau, G. oo, oh, I. close o.
[*u*] G. open u.
[u] F. ou, G. uh, I. u.

[1] As the relations of the vowels are a matter of much dispute, it may be well to give some reasons for the classification adopted here.

(1) The normal series forms, when whispered, a fairly continuous pitch-scale; (2) in pronouncing the normal vowels simultaneously with [*z*], the easiest is [*ȧ*]; passing from this in either direction, they become more and more difficult, [u] and [i] being about equally hard; (3) in pronouncing the normal vowels, in the order given, the tongue-point is gradually retracted; (4) the vowels [*a*,], [*ȧ*,], [*o*,], [*u*,] can be distinguished fairly well, while attempted nasal [*æ*], [*e*], [*i*] give [*ə*,], their dorsal articulations being in front of that of [k]. This seems to show that the normal vowels lie in a single continuous series, and that the *o*- and *u*-articulations are behind the uvula.

(5) The *y*-sounds can be formed without "rounding," and the *i*-sounds with it, without any considerable change in quality; (6) both these classes of sounds can be pronounced simultaneously with *m*; (7) attempted simultaneous [*j*] and [*u*] gives a sound very similar to [*y*]. This apparently proves that the *y*-sounds are combinations of *u*- and *i*-positions (slightly reduced?), and are not (necessarily) "rounded" *i*-sounds.

[2] To be associated with *o*, as ɛ is with *e*.

REDUCED

[ì] intermediate to [i] and [ə].
[*ì*] intermediate to [*i*] and [ə].
[è] intermediate to [e] and [ə], etc.[1]

NEUTRAL

[ə] simple voice, the unaccented vowel of E. 'fungus, wondrous.'

NORMAL COMPOUND

[y] combination of [u] and [i], F. u, G. üh, Danish close y.
[*y*] com. of [*i*] and [*u*], G. open ü.
[ø] com. of [o] and [e], G. öh, F. close eu.
[*ø*] com. of [*o*] and [*e*], G. open ö.
[ɜ] com. of [ɔ] and [ε], F. open eu.
[*a*][2] com. of [*å*] and [*æ*], B. stressed u in 'fungus'?

REDUCED COMPOUND

[ï] com. of [i] and [ù], Russian ы.
[*ï*] com. of [*i*] and [*ù*].
[ë] com. of [e] and [ò], etc.[3]

The use of most of the vowel signs requires little comment. The sign *œ*, often used for [ɜ], is avoided here in order to permit the use of *æ* instead of æ, and because of its conflicting associations; if *œ* is to be used at all, it should be for the sound intermediate to [*e*] and [*o*].[4] If roman ɜ is needed, Russian з-like *z* might be used. The sign *å* seems necessary for several reasons. The sounds æ and ε are distinguished by SWEET[5] and by PASSY[6] as here, but they use the single letter ɔ for the vowels of B. 'knot, nought,' as well as for the somewhat different one of F. 'port, note.' The distinction is just as important in the latter case as in the former, and is therefore indicated here by *å*—ɔ. The character *å* indicates the sound intermediate to the *a*-group and the *o*-group, just as æ does the one between the *a*-group and the *e*-group; and it is especially suited to American English, because commonly written with an **a**: 'all, awl, haul, talk, watch,' etc.

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[1] Indicated by a grave accent over the corresponding normal vowel.

[2] To be associated with *a*.

[3] Indicated by two dots over the corresponding normal vowel.

[4] ATKINSON, *ælfəbit*, Maître Phonétique, 1900 XV 61.

[5] SWEET, Practical Study of Languages, New York 1900.

[6] PASSY, Sons du Français, 5e édicion, Paris 1899.

iii. Modifications.

LENGTH

In many languages the time-element (duration, quantity, length) of sounds is an important factor of speech. In the Germanic tongues similar long and short vowels are often appreciably different in quality: compare English 'fairy—harry, wren—rein, pick—pique, good—food,' etc.; from which fact there has arisen the common notion that a difference in quality necessarily accompanies difference of quantity.[1] This idea however is readily proved false: in music the "short" vowel of 'sat' may in one measure be sung to an eighth note, and in another to a half note, with any noticeable difference of quality. In some languages, as French and American English, words are distinguished solely by the duration of their vowels; quantity signs are therefore often indispensable in a phonetic notation.[2]

The indication of length by doubling a letter is objectionable not only by reason of its sprawliness,[3] but because it renders impossible, in a textual notation, a distinction like that of the diphthong *ii* in 'key-ring' and the simple long *i* in 'hearing.'

The use of a colon (:) to indicate length has been adopted by many writers.[4] This may do well enough in the Romance languages, where final vowels are commonly short, but it is unsuitable in the Germanic ones, because at the end of a word it may easily be mistaken for and misprinted as a punctuation mark.[5] A modified form with angular dots[6] is rather illegible, resembling i with the dot broken off, so that in transcription 'call' looks like 'coil,' 'pause, paws' like 'poise,' etc.[7]

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[1] SOAMES, Introduction to Phonetics, 2d edition, 54, London 1899.

[2] Much of the otherwise excellent work published by the American Dialect Society is made more or less unintelligible by the lack of any systematic method of marking vowel-length.

[3] SWEET, Primer of Phonetics, 100, Oxford 1890.

[4] MICHAELIS ET PASSY, as before.

PASSY, Le Français Parlé, 4e édition, Leipzig 1897.

VIETOR, Aussprache des Schriftdeutschen, 4te auflage, Leipzig 1898.

RIPPMANN, Elements of Phonetics, London 1899.

SPIERS, as before.

[5] Yet even in Romance speech interjections sometimes have final long vowels, so that confusion may occur. For actual examples, see PASSY's Français Parlé (4th edition): "səkrɛ:", page 9, line 3, has a short vowel, while "o :", p. 11, l. 8, is long.

[6] PASSY, Éléments d'Anglais Parlé, 3e édition, Paris 1900.

[7] SPIERS, *A moyen*, Maître Phonétique, 1902 XVII 87.

The popular method of marking quantity by the macron and breve, ā, ă, ē, ĕ, etc., is unsuitable for an extensive scientific notation, because it requires the casting of new types for long and short æ, å, ɔ, ȯ, ü, n, s, etc. To avoid typographical difficulty, it has been proposed that these marks should be put after the letter modified instead of over it.[1] This plan is unsuitable for a textual notation, because if the marks used are large enough to be properly legible, they take up a great deal of space (half an em or more). As the length sign seems to be the only one needed in ordinary transcriptions, a mark like the macron, but in a different position [ˈ], is proposed here. If other signs are required in more accurate work, the following might be employed:

[ꜞ] over-long.
[˔] half-long.
[˘] short.
[ˆ] extra-short.

These are placed after the sound-sign modified.

PITCH

A common manner of indicating pitch, or intonation, is the use of slanting lines, angles and the like to mean rising, falling, high, etc.[2] This method is (or might be made) a good one, as far as it goes; but if it is used, care should be taken to provide for all necessary variations. In one system,[3] where only level, rising and falling tones are indicated, we find that the "tone-marks are put before the word they modify; if they modify a whole sentence, they are put at the end of it"; using this it would be impossible to distinguish normal "Is he ready?" with a rise throughout from "Is he READY?" with a rise through three syllables and a low tone for the fourth.

To indicate pitch with considerable accuracy, ordinary musical notation is sometimes employed. This system is hardly suitable for textual use, because of its bulkiness; it might be replaced by numerals corresponding to the semitones: [^{0}] for the lowest note of speech (which is usually a little higher than the lowest singable note), [^{1}] for the next semitone, [^{2}] for the next, etc. This provides for a variation extending

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[1] VIANNA, *kɔrɛspõdã:s*, Maître Phonétique, 1890 V 105.
HALDEMAN, Analytic Orthography, 83, Philadelphia 1860.

[2] SWEET, Primer of Phonetics, 65, Oxford 1890.
PASSY, Sons du Français, 5e édicion, 71, Paris 1899.
SIEVERS, Grundzüge der Phonetik, 5te auflage, 225, Leipzig 1901.

[3] SWEET, Primer of Spoken English, 3d edition, 3, Oxford 1900.

through nine semitones, a range that is not commonly exceeded in speech. If the complete octave were needed, superior 10 could be indicated by [^{X}], and 11 by [^{Y}], the groups [^{10}], [^{01}], [^{12}], etc. thus being left for glides within a vowel or syllable; the second octave could be marked with [*], or some other arbitrary sign. Taking the lowest note as do, we should have these correspondences:

[^{0}] do	[^{3}] ri, me	[^{6}] fi, se	[^{9}] la	[*^{0}] do
[^{1}] di, ra	[^{4}] mi	[^{7}] sol	[^{X}] li, se	[*^{1}] di, ra, etc.
[^{2}] re	[^{5}] fa	[^{8}] si, le	[^{Y}] si	

The pitch-marks should be placed before the syllables modified.

STRESS

The common method of indicating stress in English, by a mark (′) after the accented vowel or syllable, is unsatisfactory because it affords no means of distinguishing ordinary 'wi·thout' from artificial or emphatic 'with·out'; the use of a mark on the vowel is objectionable for the same reason, and because of typographical difficulties with *v*, *ɔ*, *å*, *â*, etc. The use of an accent before the stressed syllable, as in one of PASSY's systems, is entirely unsuitable for English texts because of conflicting associations with the ordinary use of the accent. The best system seems to be that employed by SWEET[1]: [·] for strong stress, [:] for medium, and [-] for weak. If other distinctions are required, they might be indicated by combinations of these marks, as [··] for very strong, corresponding to orthographic italics. The stress signs are placed at the beginning of the syllable.

SYLLABLES

The common philological notation for the nonsyllabic function is the mark ̂ under the sound-sign modified. As this requires new types in most cases, a more practical means of indicating a nonsyllabic vowel would be to put the same sign after the vowel: [*a*̭], [*e*̭], etc.

On the analogy of [˘̭] we might use [ˌ], the turned length sign, to indicate a syllabic consonant, without thereby implying any direct or fixed relation between quantity and syllabic function; to use the same sign for these two things, as some writers do,[2] is not advisable, because syllabic and nonsyllabic sounds alike can be either short or long.

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[1] SWEET, Elementarbuch des Gesprochenen Englisch, 3te auflage, Oxford 1895.

[2] BELL, Sounds and their Relations, Salem 1881.

LLOYD, Northern English, Leipzig 1899.

In the description of a textual notation given below these signs are not used, since in English the vowel-diphthongs have the second portion nonsyllabic, while syllabic consonants occur only before a consonant or a pause.

SONATION

[*P Φ F θ T*], etc. For capital *ʃ* the letter *ʃ* can be used.

SURDATION

[$^{b\ m\ w\ v}$], etc. If it is necessary to distinguish whispered sounds from surds, they can be indicated by smaller letters printed on the line instead of superior.

EXPLOSION

An occlusive before a pause or another occlusive has little audibility unless it is exploded; in a scientific notation there is need of signs to indicate the explosion: [ʽ] surd, [ʻ] whispered, [ʼ] sonant. The last of these differs from the ordinary vowel *ə* in having much less duration, and loudness, or sonancy, as may be seen by comparing 'Rhoda' *roudə* with 'road' *roud.* The sign [ʽ] might be used in a very accurate textual notation to indicate aspiration of surds before any sound, as 'stay' *stʽei,* 'try' *tʽrai,* etc., although in such cases the [ʽ] can hardly be considered a separate sound, but is rather a sign that the following vowel or strictive commences surd.

Where it is necessary to indicate the absence of explosion, this may be done by the use of a period; English 'actor, Bagdad' have [*k.*], [*g.*], not [*kʽ*], [*gʼ*] like the similar French words.[1]

NASALIZATION

The Polish and Portuguese signs for orinasal vowels have come into general use among phonetists; unfortunately neither system is very practical, since only two letters are available in each (ą, ę; ã, õ). In a scientific notation we can, as HALDEMAN suggests,[2] imitate the Polish sign by a turned apostrophe [˛] after the letter modified: Fr. 'vin' [*væ˛*], 'vent' [*vɑ˛*], 'vont' [*vo˛*], 'un' [*ə˛*]. These vowels occur independently in English in some interjections, as [*æ˛hæ˛*], [*hə˛*], etc.; they may often be distinguished, but are not distinctive, in cases like [*se˛nd*] 'send,' [*wi˛nd*] 'wind.'

Complete nasality, formed by closing the oral passage at the [k]-position, may be indicated by [,]. While the nasal vowels perhaps do not

[1] PASSY, as before, 121.

[2] HALDEMAN, as before, 46.

occur in any language, they are important for experimental purposes (p. 107, note 1).

Modification of one sound toward another can be represented by the use of inferior letters, as [$ə_ɹ$] in a common American pronunciation of 'winters,' [$s_ι$], [$m_ι$] in Russian '7,' etc.

Advancement of articulation may be indicated by [,], as [$t_,$] postdental, [$t_{,,}$] interdental, [$t_{,,,}$] linguālabial; retraction by [˛], as [$t_˛$] postalveolar, [t˛] postpalatal.

Any modification desired might be indicated by inferior numerals; for instance [r_1], [r_2], [r_3], etc. to show the number of flaps.

c. Textual notation.

A notation used to transcribe a continuous text in a single language must differ somewhat from the scientific notation given above; especially in that digraphs like $a_ɹ$, $a_ι$, a_1, a_2, a_3 for simple sounds are not permissible, except for length, stress and pitch modifiers; typographical distinctions like *b*, b, ^{b} should in general be avoided, except where it is desirable to call the student's attention to some unfamiliar modification or class of sounds in a foreign language.

The following list includes signs for the American English sounds that need to be distinguished in an ordinary literary text; sounds that occur only or chiefly in exclamations are not taken into account.

b 'oBey'; *p*[1] 'aPPear'; *m* 'oMit'; syllabic *m* 'cup AND saucer'; *v* 'leaves'; *f* 'leaF'; *w* 'wight,' 'white' *hwait.*[2]

d 'riDer'; *t*[3] 'wriTer'; *n* 'hoNor'; *n*ˡ 'teNDS';[4] syllabic *n* 'listEN'; *ð* 'eiTHer'; *ϑ* 'eTHer'; *z* 'raises razes'; *s* 'miss'; *s*ˡ 'misTS';[5] *ʒ* 'viSIon,' 'age' *eidʒ*;[6] *ʃ* 'fiSH,' 'rich' *ritʃ*,[6] 'nature' *neitʃə*; *r* = [ɹ]

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[1] Sometimes pronounced where not written, as 'warm( )th, dream( )t, some( )thing.'

[2] A few speakers do not pronounce the *h* in this and similar words, so that 'white' = 'wight,' 'where' = 'wear,' 'which' = 'witch,' etc.

[3] Often inserted where not written, so that 'Welsh' = 'Welch,' 'dense' = 'dents.' The consonants *d t n l* may become nearly interdental when adjacent to *ð* or *ϑ*, as in 'earthen,' and are slightly retracted after apical vowels, as in 'bartered.'

[4] In careful or emphatic speech the d is often pronounced, so that the word is perfectly distinct from 'tens.' In some pronunciations this long *n* does not seem to be distinguished; likewise with long *l*.

[5] In artificial and emphatic speech the t is often pronounced: *mists*.

[6] In these consonant groups the occlusive and fricative belong the same class; either may be slightly different from ordinary *d t ʒ ʃ*. In my pronunciation the paginals and *r* have about the same lip-position as *w*.

'merry';[1] *l* = [*l*] 'holy wholly'; *l*' 'holds';[2] syllabic *l* 'handles'; *g* 'finger'; *k*[3] 'choir quire'; *ŋ* 'singer'; syllabic *ŋ* 'lookingglass'; *j* 'you ewe,' 'Hugh hue hew' *hjuu*; *h* 'hold.'

The surd occlusives, *p, t, k,* when not followed by an occlusive are usually aspirated, though very weakly before an unstressed vowel. The importance of this aspiration is shown by the fact that English-speakers are liable to mishear unaspirated *p t k* as *b d g*.[4] The consonants *k g ŋ* vary somewhat according to the neighboring sound; they do not however reach the full prepalatal position, as sometimes happens with French gu, qu: [*cɛl*] 'quel,' [*ci*] 'qui,' etc. The sonant occlusives and fricatives are usually whispered before a surd; the sonant occlusives become surd after a surd, but are kept distinct from *p t k* by the absence of aspiration; *h* tends towards sonancy after a sonant. The glottal occlusive *ʔ* seems to be often substituted for *p, t* or *k* between orinasals, as in 'bluntness.'

ii 'see sea, key-ring'; [*i*i]; with some speakers nearly [iˈ].

*i*ˈ 'spearing, period'; [*i*ˈ]; some replace this by a diphthong, *iə*; similarly with long *e, o, u.*

iə̣ 'spears, piers peers'; [*iə*].

i 'spirit, busy, give'; [*i*], nearer to [*i*] than to pure [*i*].

ɪ 'studded studied, accept except, palace, lettuce'; unstressed and therefore rather variable, [*i*], [*ė*]; only preconsonantal.

ị 'busiest, sixtieth, cereal serial'; unstressed; approximately [e], varying towards [ë] or [*i*]; chiefly prevocalic.

ei 'say, weight wait'; approximately [*ė*i], but the second portion seems to vary towards [e]; before *r* or *ə* sometimes replaced by long [*e*].

e 'says, men, meant'; [*e*]; before *g* and *ŋ* this may become slightly diphthongal, *ee*, the second part being [e]: 'beg, length.'

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[1] Public speakers and singers often use a *r* = [*r*], with one or more flaps.

Some Americans, like many Londoners, insert *r* as a hiatus-filler after *ə* and long *å*, *a*: 'idea ( ) of, draw( )ing, Shah ( ) of,' etc. This *r* is probably not due, as has been supposed (Lloyd, Phonetische Studien, 1892 V 89), to apicality of the vowels, since it is used chiefly by persons who cannot (or at least do not) employ apical vowels in 'hard, furthers'; it is merely the result of analogy, like so many other speech changes (for example 'nothing—nothin' from a similar variation in present participles; 'we was—he was' from the lack of inflection in all other preterits; 'different than' from 'other than'). Most words ending in *ə*, and many in long *å, a,* are written with an r that is regularly pronounced before a vowel; this prevailing duality of pronunciation has simply been extended to all words with these endings.

[2] In artificial or emphatic pronunciation sometimes *houlə̣z*, perfectly distinct from 'holes.'

[3] Sometimes inserted where not written, as 'leng( )th, streng( )th.'

[4] Cust, *Report on Korean*, Transactions of the Philological Society, 1877-8-9, p. 615.

*e*ˡ 'cAring, fAIry, bEArer'; [ɛˡ].

eə̯ 'cAREs, fAIRs, bEARs'; [ɛə˞]; sometimes replaced by *ê*ˡ [ɛˡ˞].

*æ*ˡ 'bAd, pAth, pAst, hALve, smAsh, sAnd, mAn'; nearly the same in quality as short *æ*, with perhaps a slight tendency toward [ɛˡ].[1]

æ 'bAde, hAth, hAst, hAve, sAsh, plAnned, bAn'; sometimes diphthongized to *æe* before *g* and *ŋ*, as in 'rag, rang.'

*a*ˡ theoretical vowel of 'half, path, past,' etc., [aˡ]; used chiefly by those who naturally employ long *æ* or *a*.

*a*ˡ 'ALms, cALmer, fAther'; usually on the [ɑ]-side of [*a*]; in eastern New England perhaps more commonly on the [a]-side.

a 'yAcht, knot, comma, bother'; identical in quality with the long vowel in most parts of the United States.

*â*ˡ 'ARms, hEARt, fARther'; [*a*ˡ˞] or [aˡ˞]; the corresponding short vowel may be distinguished in weak syllables, as 'pARtake.'

ai 'AIsle Isle, AYE EYE, high, hEIght'; [*à*ì], the final element as in *ei*; in the South sometimes nearly *a*ˡ (*aə*? *aæ*?).

au 'how, OUt, lOUd'; [*à*ù], with second element varying toward [o]; in the South the first element is reduced *æ* or even *e*.

*å*ˡ 'hAll, dAUghter, sought, tAUght, wALk.'

å 'hAlt, wAter, thought, cAUght, wAsh, wAtch, squAnder,' identical in quality with the long sound; not distinguished by some speakers, who use *a* or *å*ˡ instead.

oi 'bOY, hOIst'; first portion [*å*], [ɔ] or [*o*], second as in *ei*.

*o*ˡ 'sOAring, pOUring, story'; [ɔˡ] or [*o*ˡ]; by some speakers replaced by *å*ˡ.

oə̯ 'wORn wARn, sOARs, pOURs, fORward, fORm, fORce'; [ɔə˞] or [*o*ə˞]; by some not distinguished from long *å*.

ou 'sEW sO, sOUl, cOAt'; [*ò*ù], second portion as in *au*.

ò used by a few speakers in 'whole, wholly, stone, coat, only,' etc.; [*ò*]; obsolescent.

u the unstressed sound corresponding to stressed *uu*, as in 'annual, gradual'; one form of unstressed "long o," as in 'following'; chiefly prevocalic; [*u*] or [o].

u 'good, foot, book, bUsh, cUshion, fUll'; slightly reduced [*u*].

ù one form of unstressed "long o" before a consonant or pause, as in 'follows, disobey'; sometimes distinguishable, though never distinctive, in trisyllabic 'usually, gradually, actually'; variable between [*ù*] and [*ò*].

---

[1] In eastern New England this vowel seems to be rather uncommon, short *æ* or long *a* being used instead, as in southern England.

*u*ˡ 'mooring, enduring';[1] [*u*ˡ].

uẹ 'moors, endures';[1] [*uə*ɹ].

uu 'mood, boot, knew';[1] [*u*u], in some pronunciations nearly [uˡ].

ə 'Augusta, fungus, son sun'; in most parts of the United States the stressed vowel is hardly to be distinguished from the unstressed one, [ə]; often used by restressing for "short o" in 'what, was, because, from,' etc.; often inserted where not written, as 'chas()m, rhyth()m, fi()le,' etc.

əi a rare form of unstressed "long i"; [əi].

əu one form of unstressed "long o," as in 'follows, following.'

ẹ 'altars alters, manners manors'; [əɹ], might be transcribed as syllabic *r*, from which it is very slightly different.

*ṿ*ˡ 'furze firs, serf surf'; a point-modified vowel with dorsal articulation rather variable, from [ɜ] nearly to [*ë*], [*ö*], [*a*], [ə]; in New York and vicinity often *ṿi*, with same final element as in *ei*, *ai*, *oi*. Long dorsal *v* may occur in 'stirring, purring,' but the short vowel *ə* seems to be much more common in such cases.

Monosyllabic vowel triphthongs, as *aiẹ*, *auẹ*, etc., seem to sometimes be used; they are not easy to distinguish from the dissyllables *ai-ẹ*, *au-ẹ*, etc. Theoretically 'flowers' has two syllables and 'flours' one; in ordinary pronunciation they are identical.

Many persons do not use the point-modified vowels at all, but employ the dorsal ones instead, so that 'arms' = 'alms,' 'leader' = 'Leda,' etc., as in southern England. A serious fault of the alphabet used in Le Maître Phonétique, and of that of Dialect Notes, is the failure to provide any suitable signs for these *r*-modified sounds.

In a similar way could be constructed textual notations for French and for German. In the former the chief difficulty would be the *a* of 'patte' *pat*, 'part' *pa*ˡ*r*, as this italic form of a is made for only a few styles of type; it might be replaced by roman a or A. Such notations as *an*, *aŋ*, etc.,[2] should not be used for the nasal vowels, since they encourage the foreigner's prejudice against learning or using the proper pronunciation; the signs ***a ε o з*** could be used for these sounds. The French sound-system, as reckoned by Passy,[3] would then be written *b p m v f w d t n*

[1] Stressed "long u" following any lingual consonant other than *k* or *g*, in the same word, has no *j* in most parts of the United States.

[2] Soames, Introduction to Phonetics, 2d edition, London 1899.

Sweet, Primer of Phonetics, Oxford 1890.

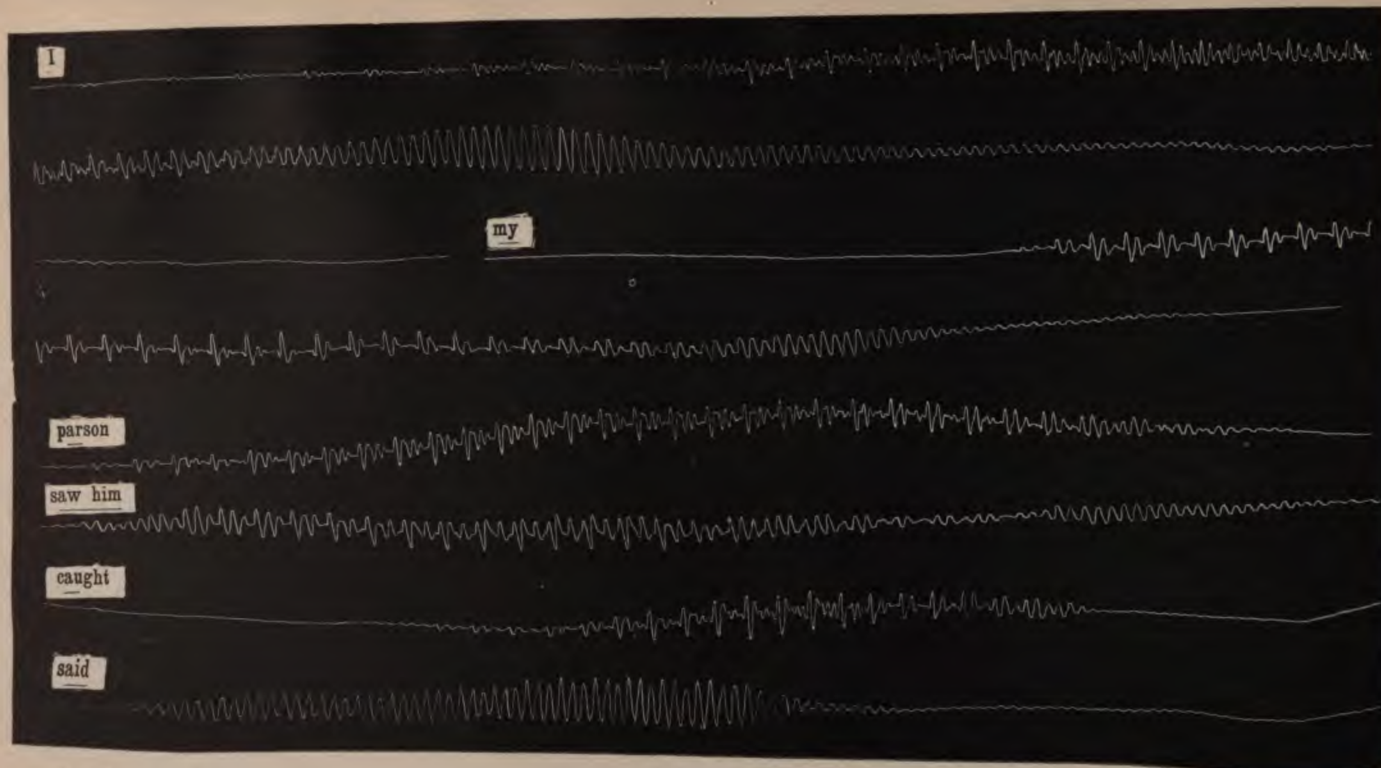
[3] Passy, as before, 133.

z s ʒ ʃ l r ɲ ɭ ɥ g k (*h*) *i e ɛ a ɑ ɔ o u ɜ ø y ɒ* **ɛ ɑ o ɜ**, each of the vowels except *ɒ* being capable of lengthening without difference of quality. German may be transcribed with the signs *b p m v f d t n z s* (*ʒ*) *ʃ l r j ç g k ŋ* (*ɣ*) *χ ʔ h iˈ i eˈ ɛ ɛˈ aˈ a ai au ɔ ɔy* (or *ɔi*, or *ɜi*) *oˈ u uˈ ɜ øˈ y yˈ ə*; if the quality of short i, u, ü needs to be distinguished, *ɩ ʋ ʏ* could be used for them.

The use of the stress-marks can be much simplified in texts where the nomic word-division is retained.

Weak-stressed syllables do not generally need to be marked as such, except in the case of monosyllables.

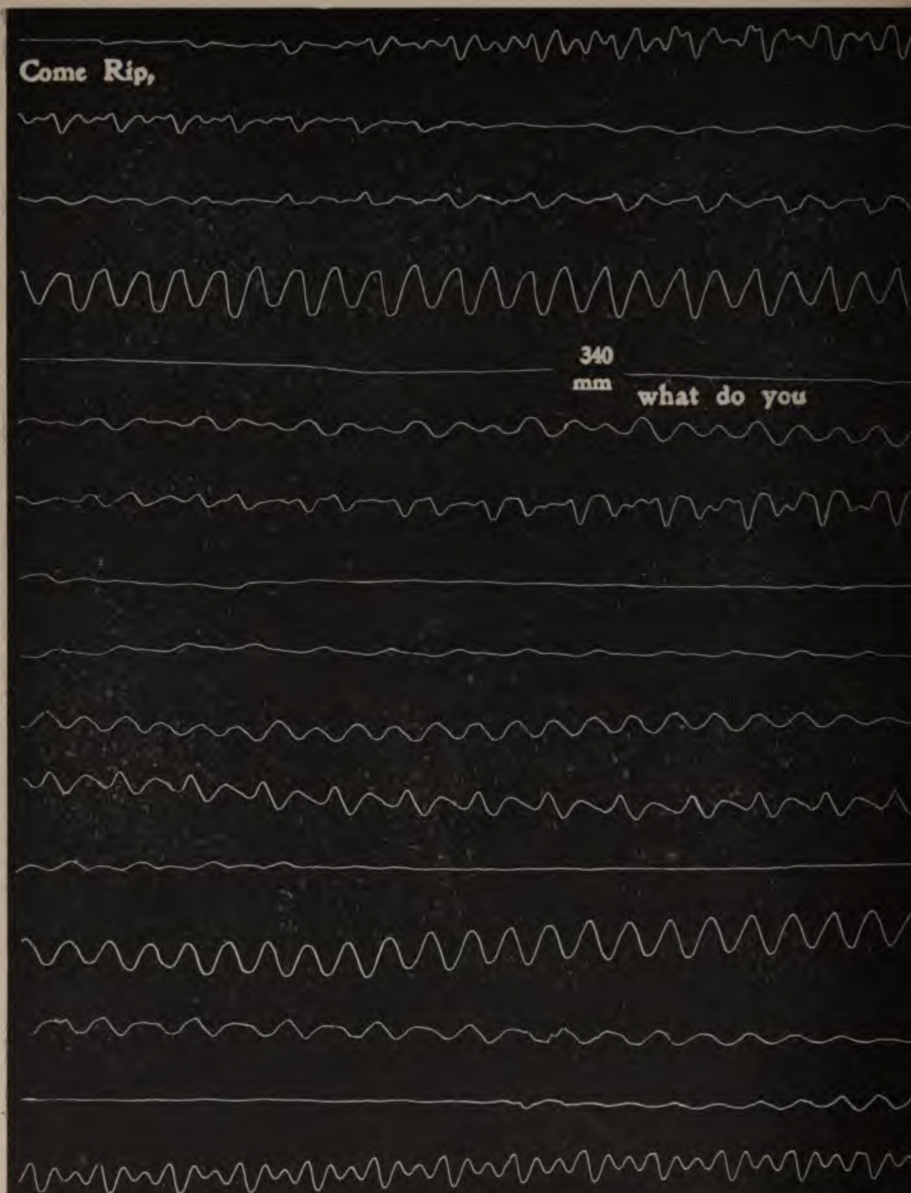
A large number of polysyllables in Germanic languages have the first syllable stressed; in the Romance languages, except French, the penult is commonly accented; the · can therefore be omitted before these syllables.



($1^{mm} = 0.0016^{s}$.)

PLATE II.

Curves from *Cock Robin, Series II.*



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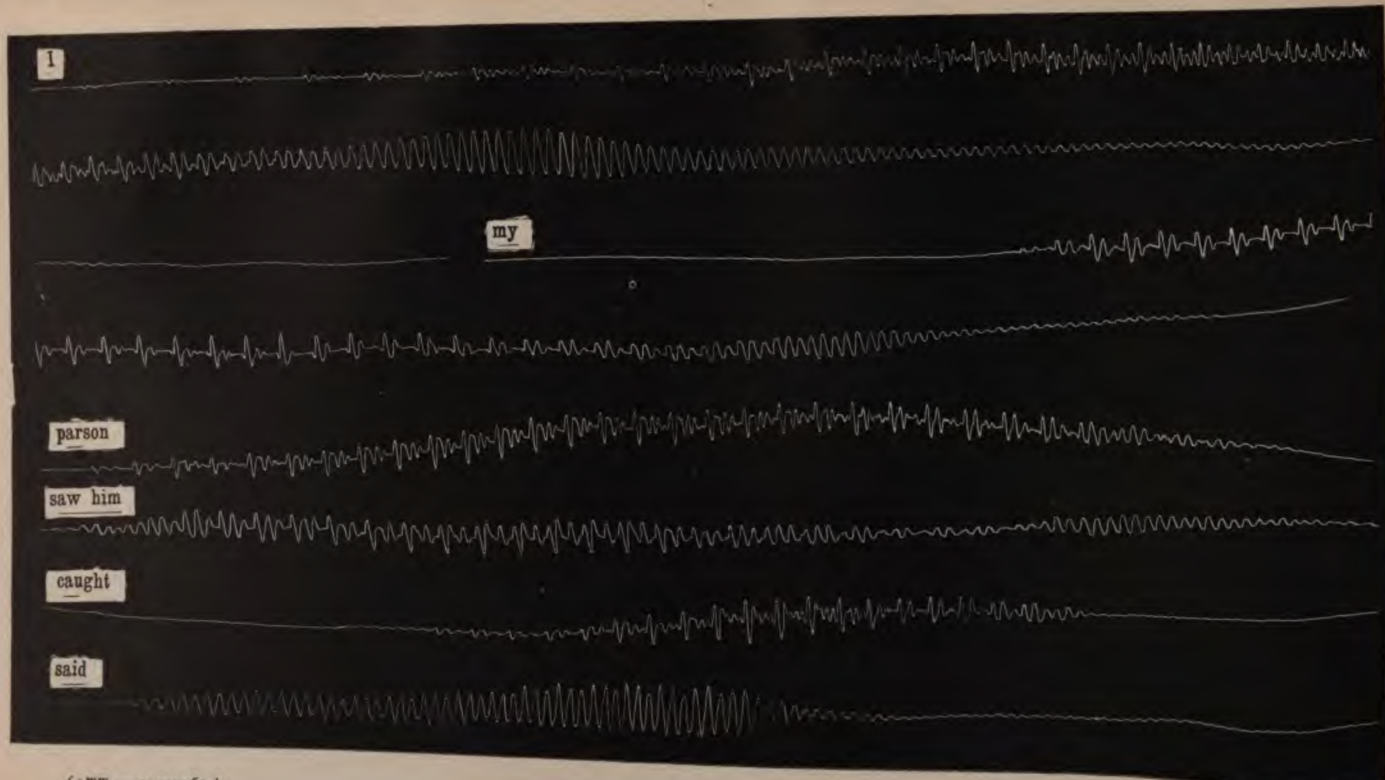
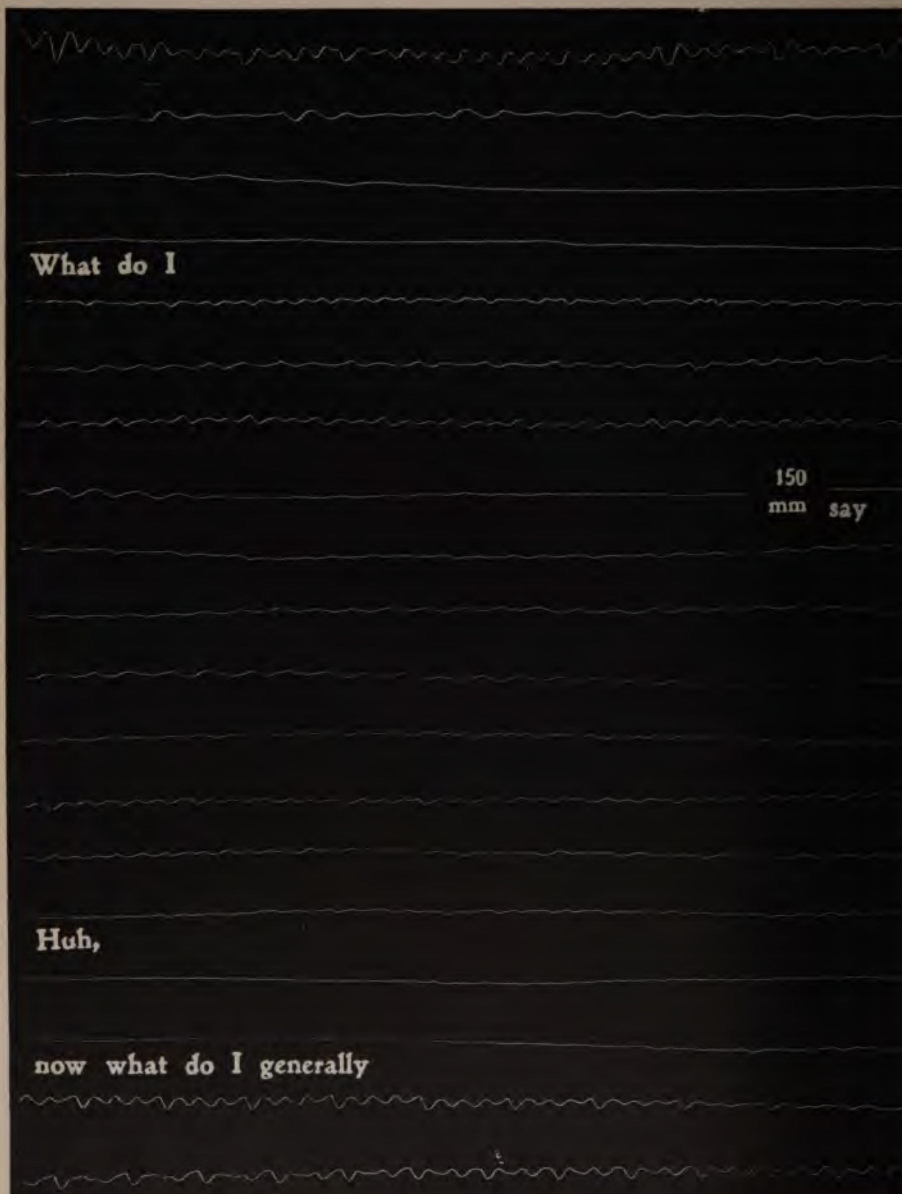


($1^{mm} = 0.0016^s$.)

PLATE II.

Curves from *Cock Robin, Series II.*



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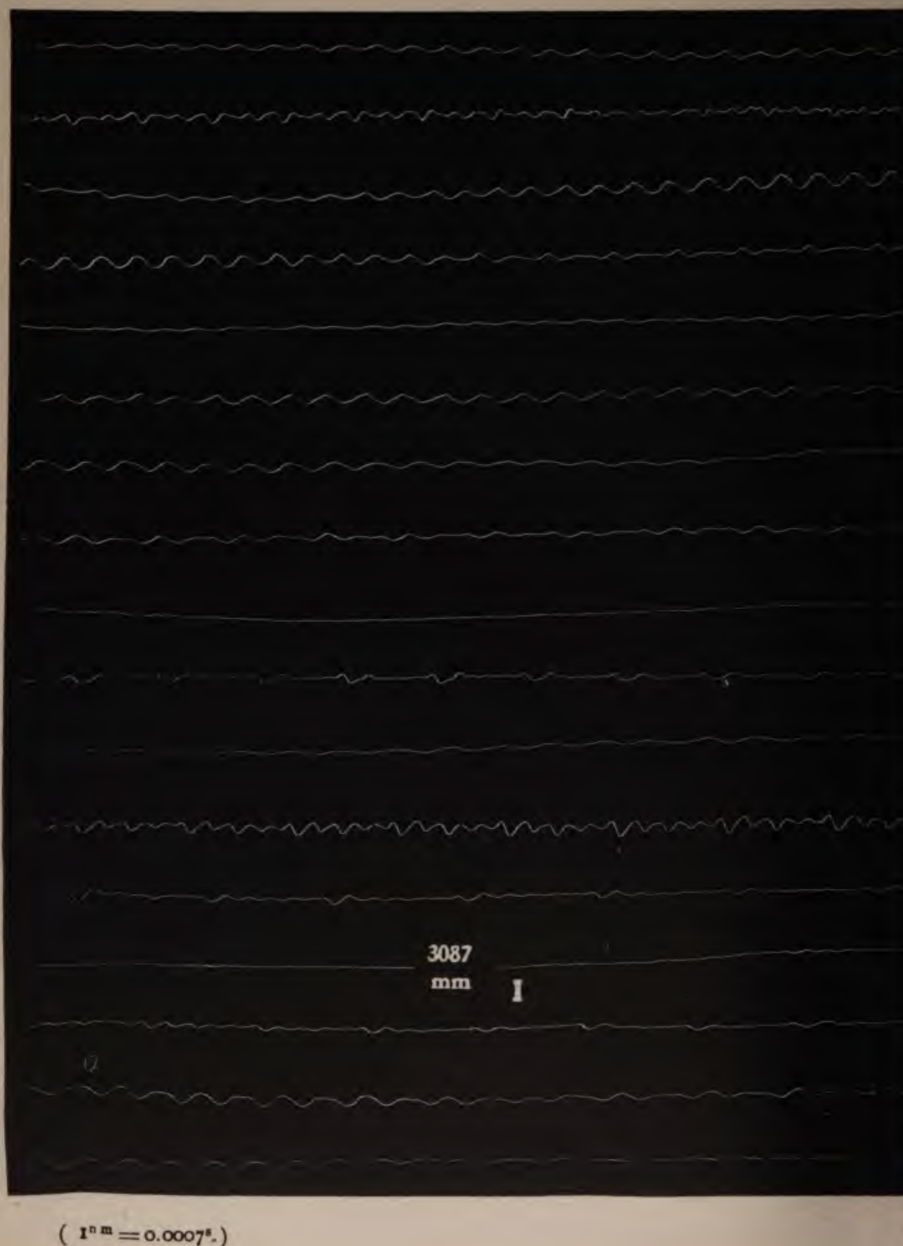

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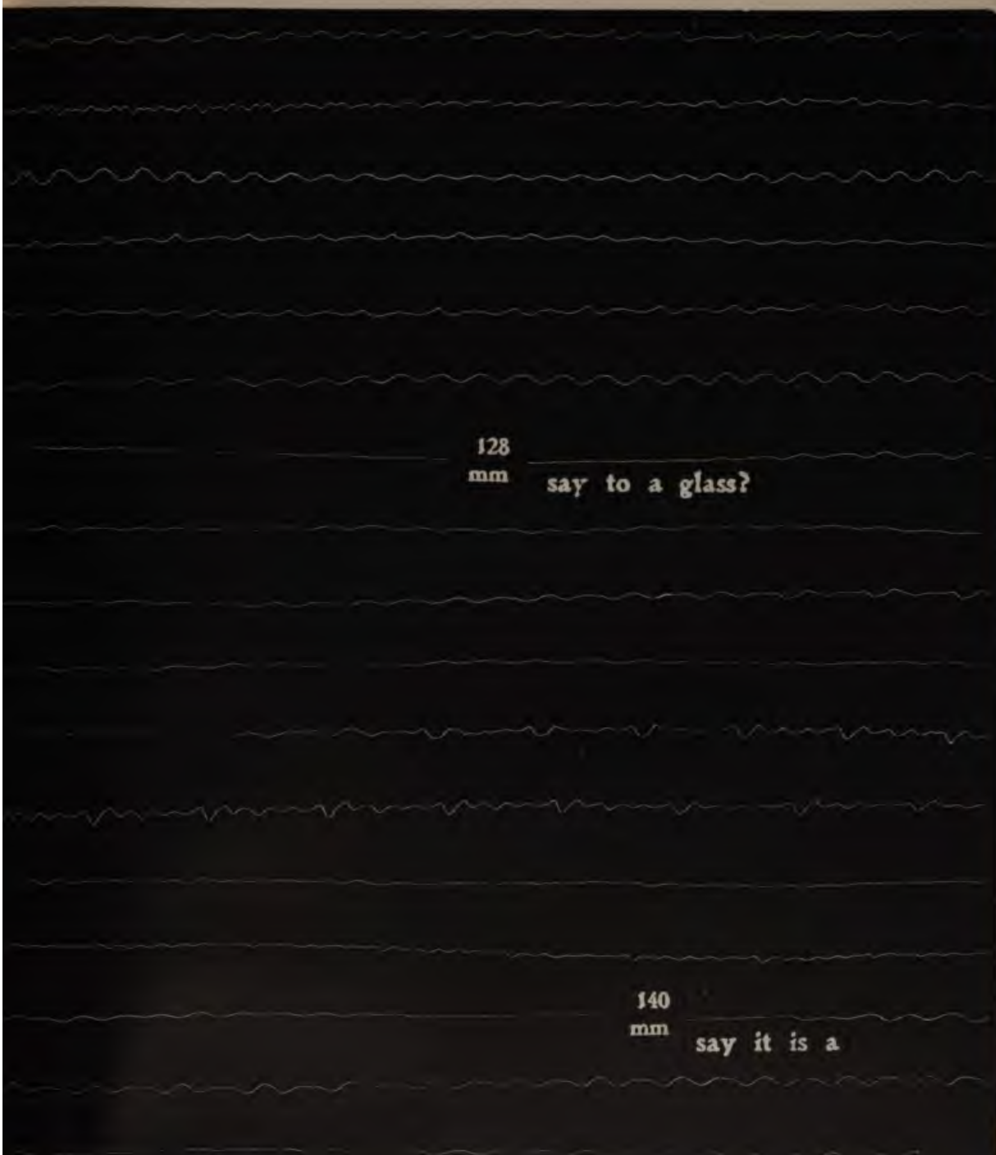
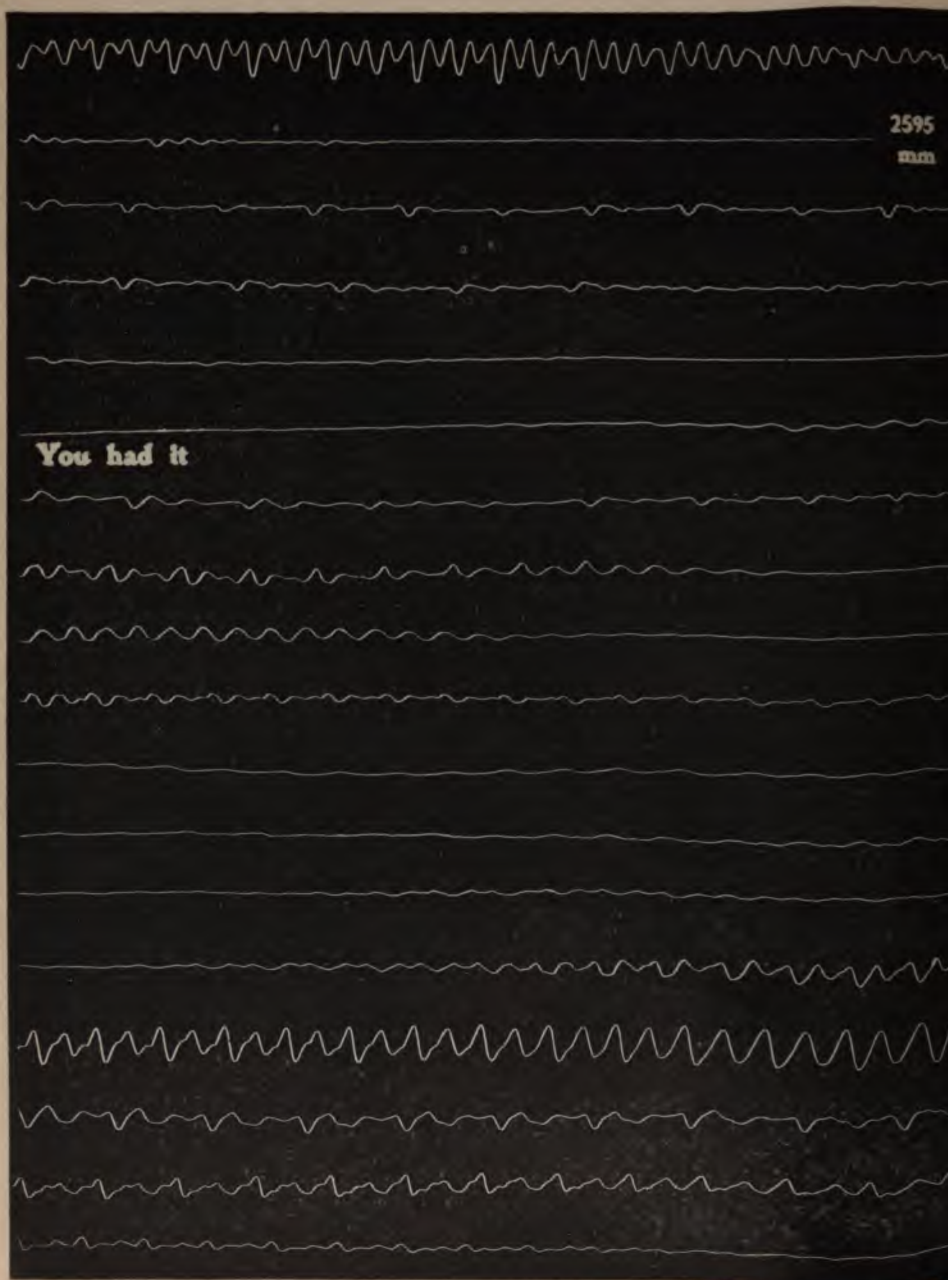
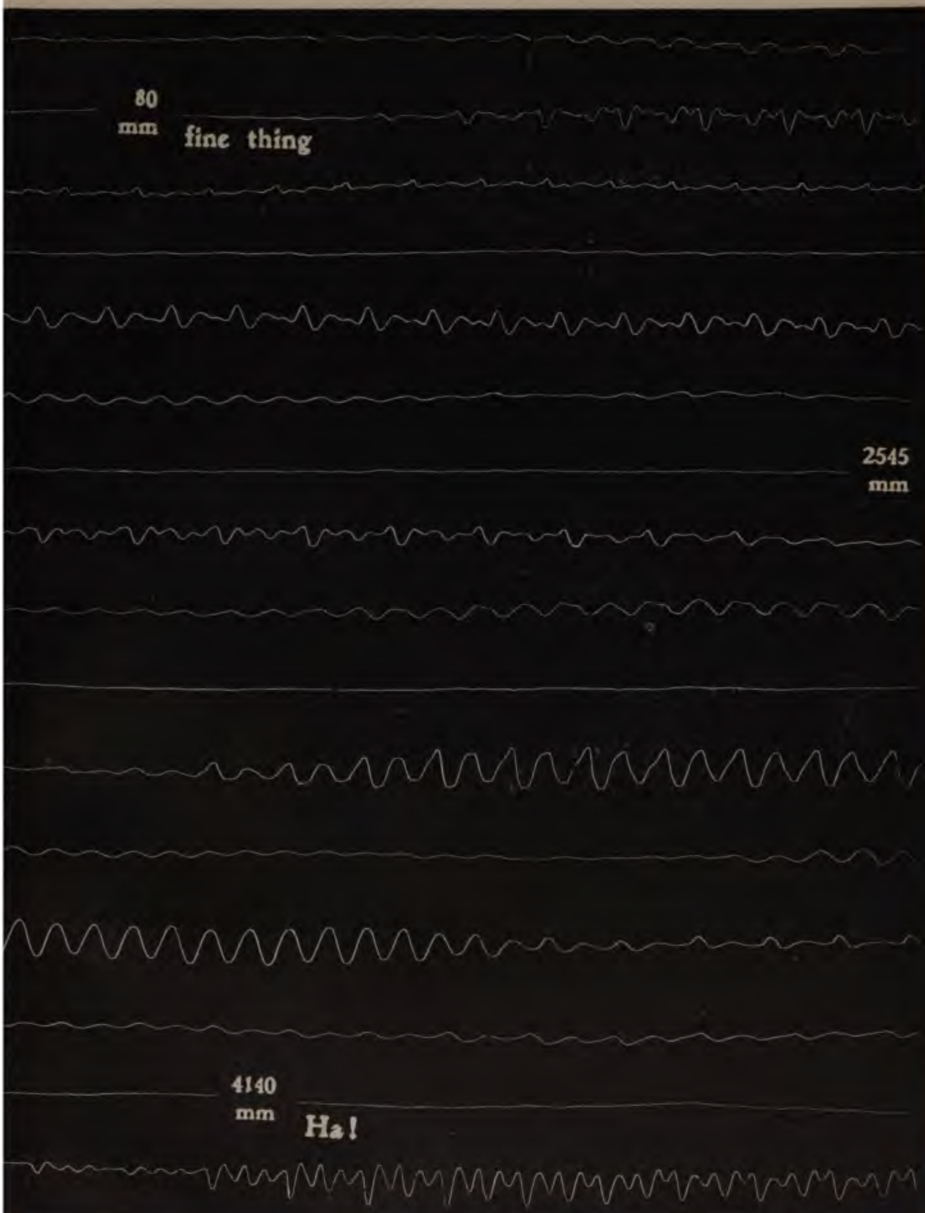


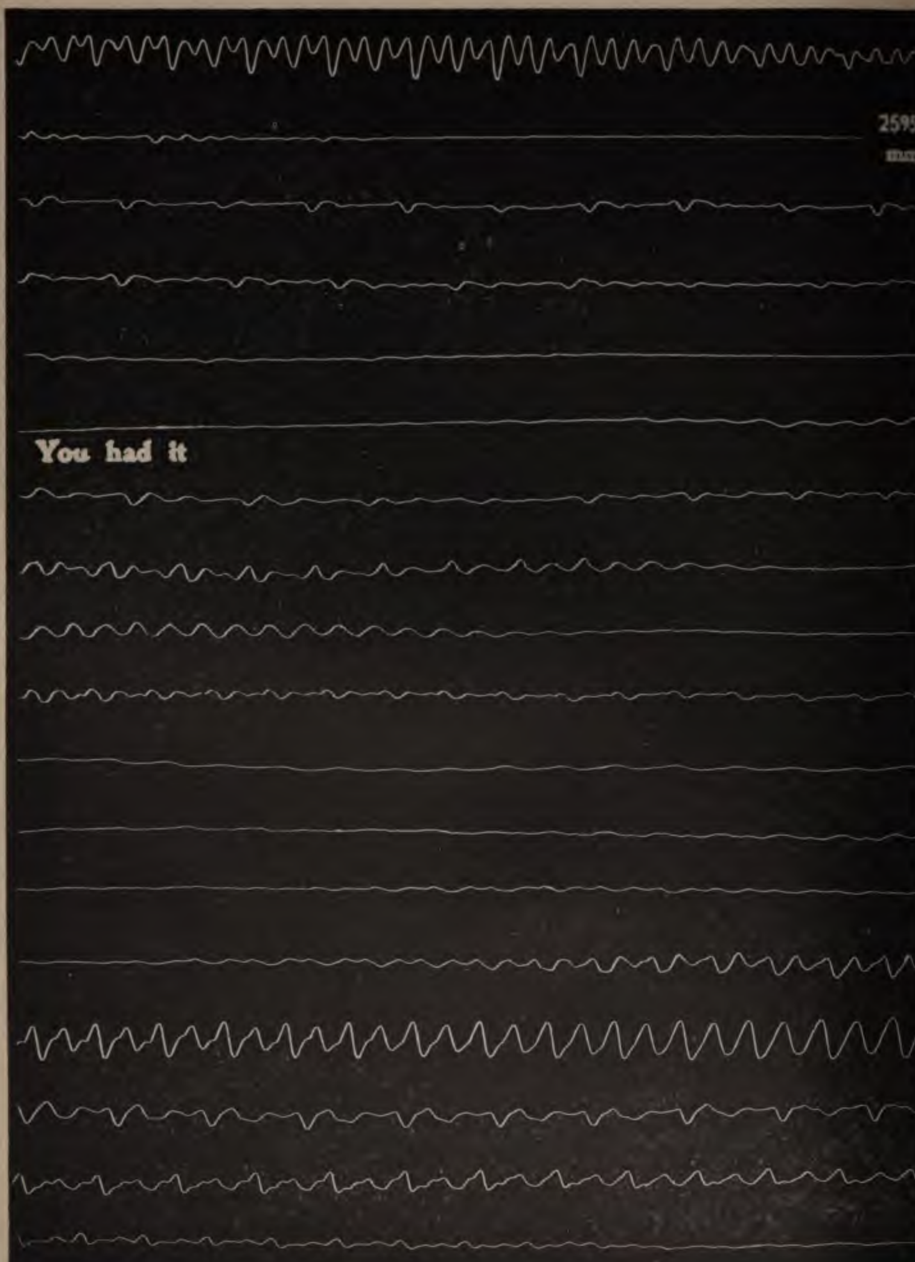
TE V. *Rip Van Winkle's Toast*, by Joseph JEFFERSON. (Block III.)



($1^{mm} = 0.0007^{s}.$)

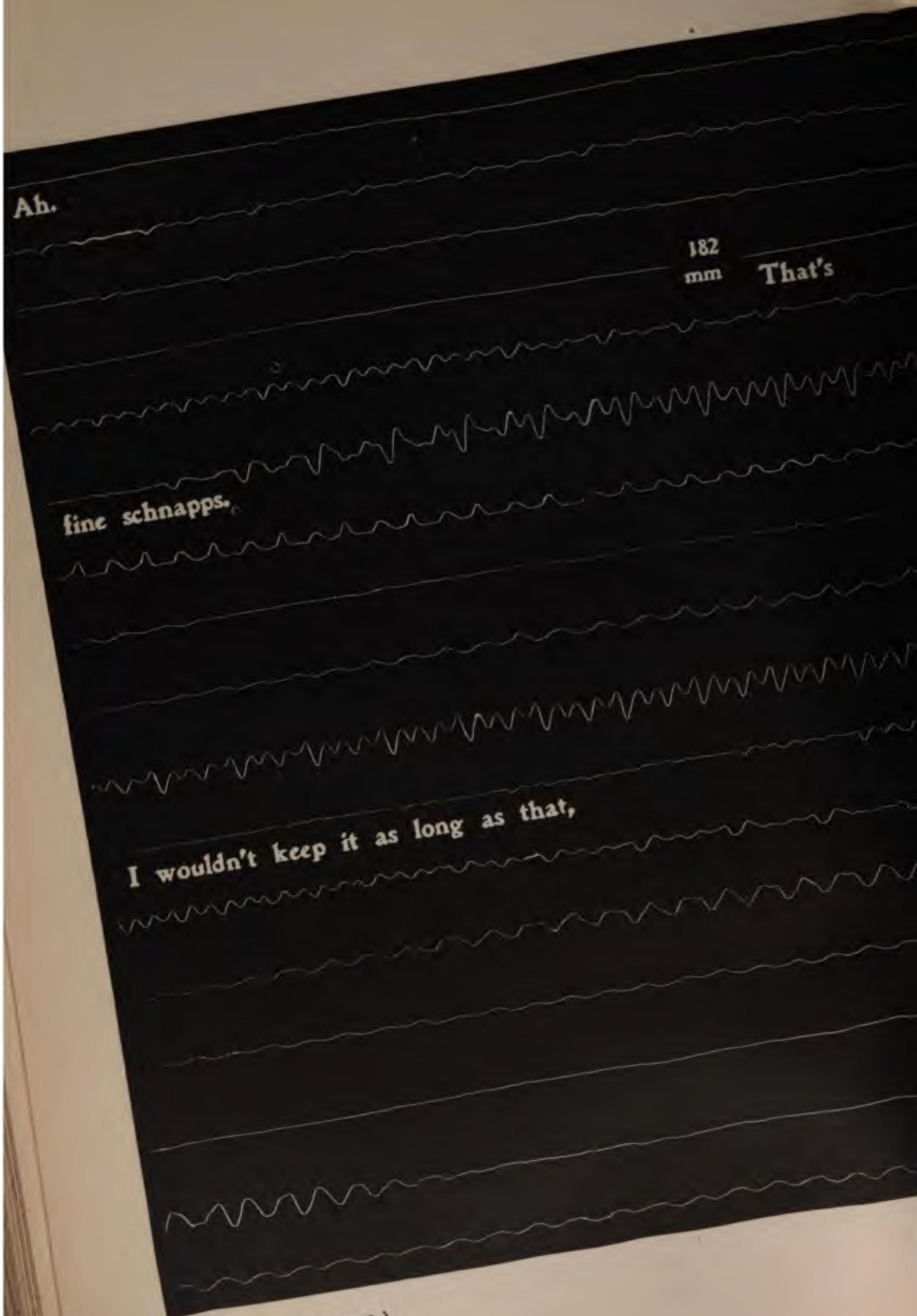


I. *Rip Van Winkle's Toast*, by Joseph JEFFERSON. (Block IV.)

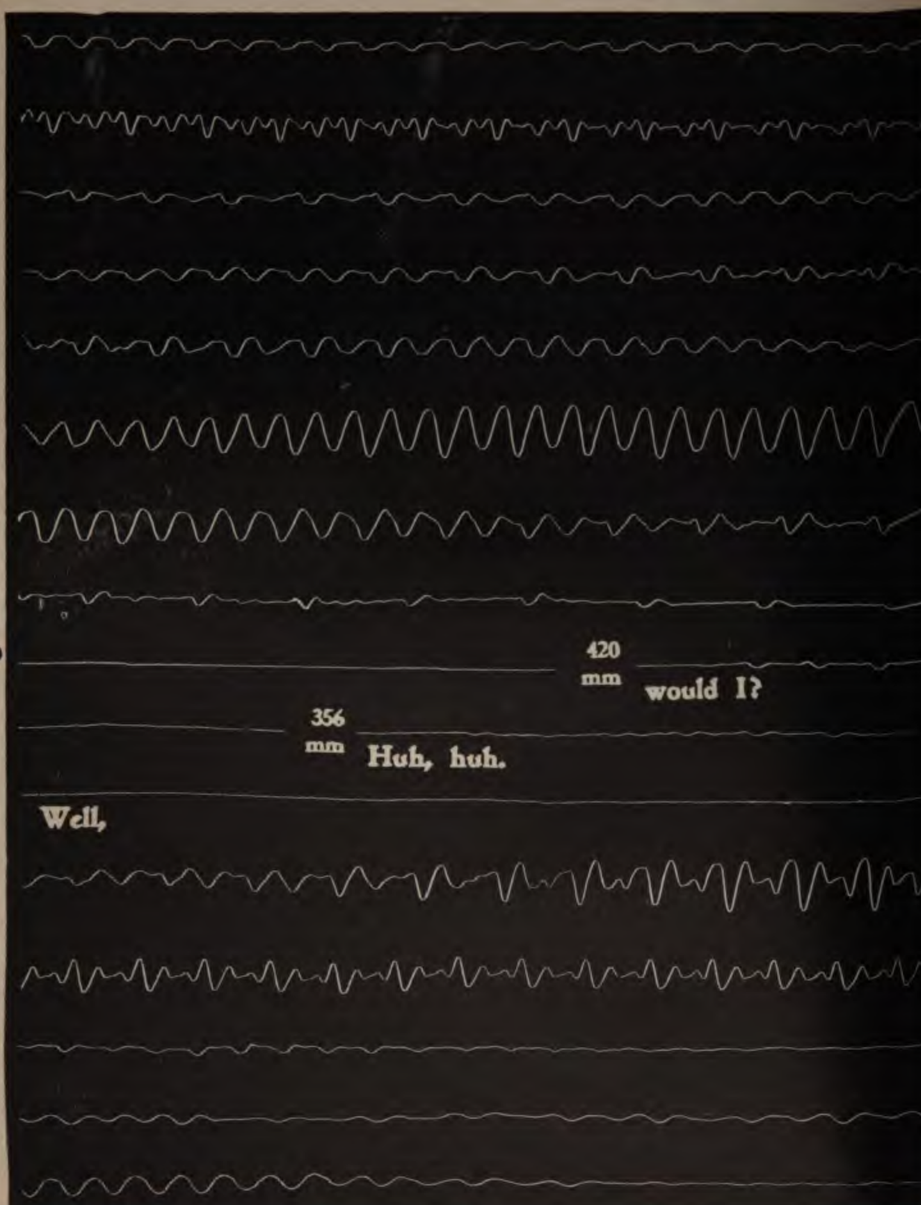


($1^{mm} = 0.0007^s$.)

PI

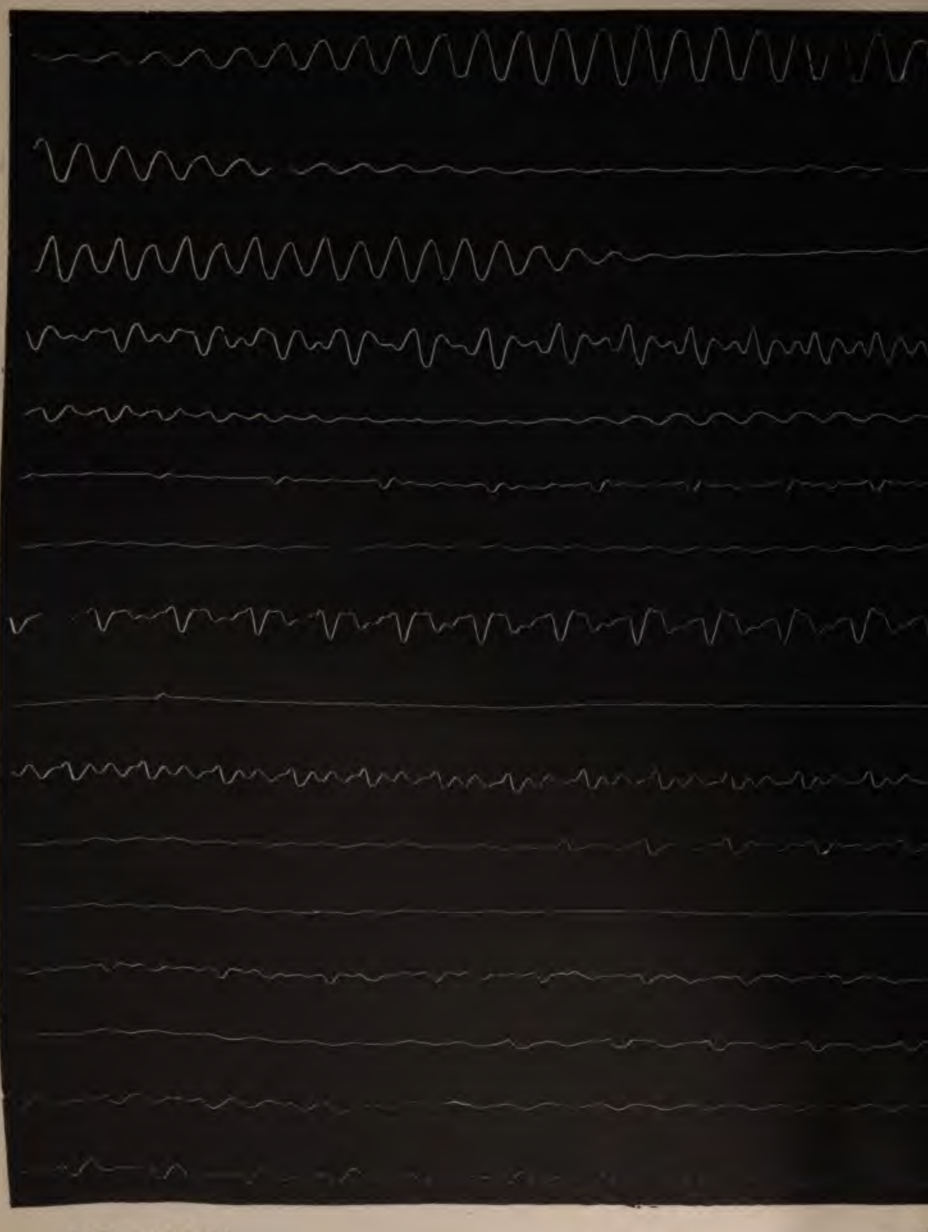

Ah.
182
mm
That's
fine schnapps,
I wouldn't keep it as long as that,

($1^{mm} = 0.0007^{s}$.)



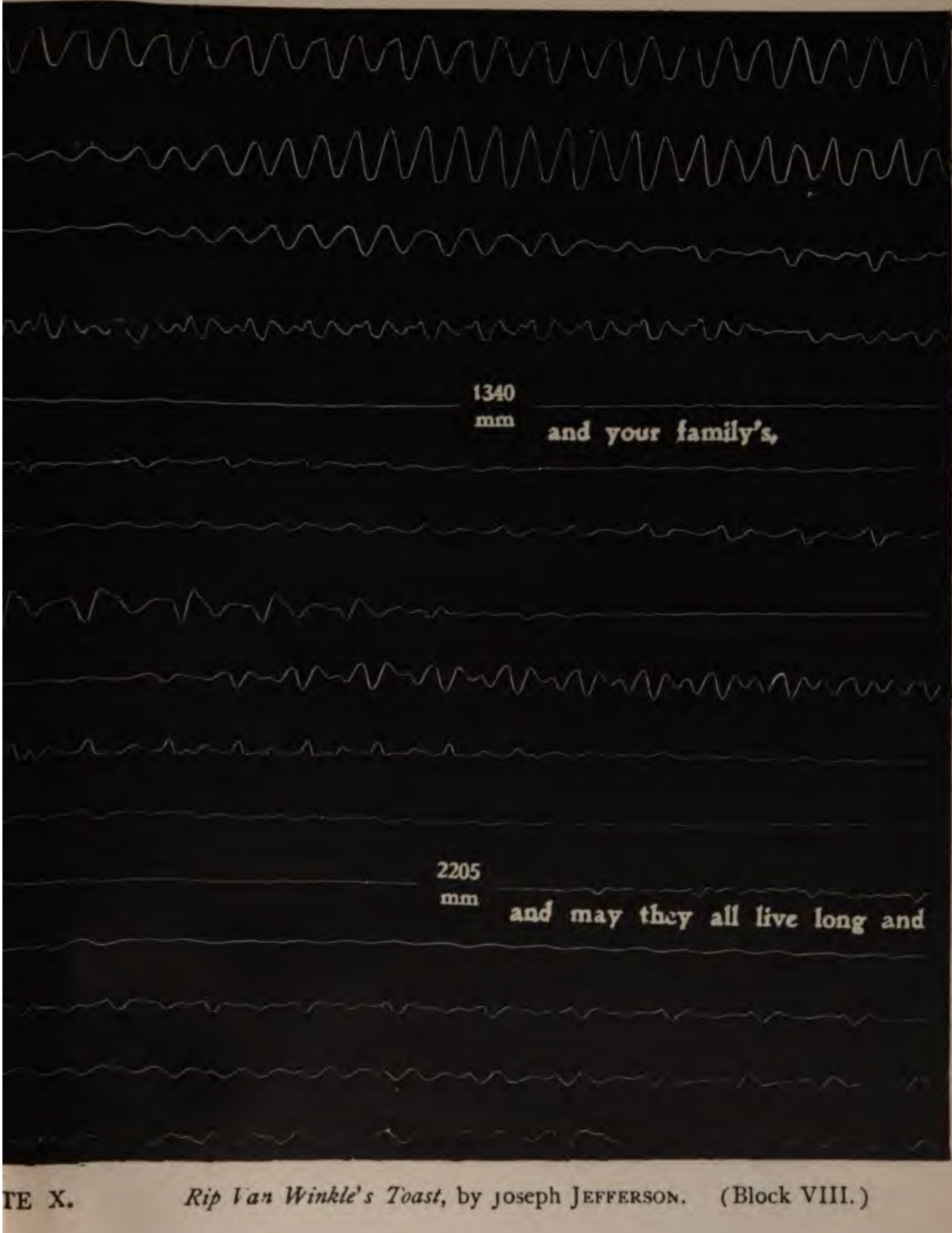
($1^{mm} = 0{,}0007^{s}$.)

P

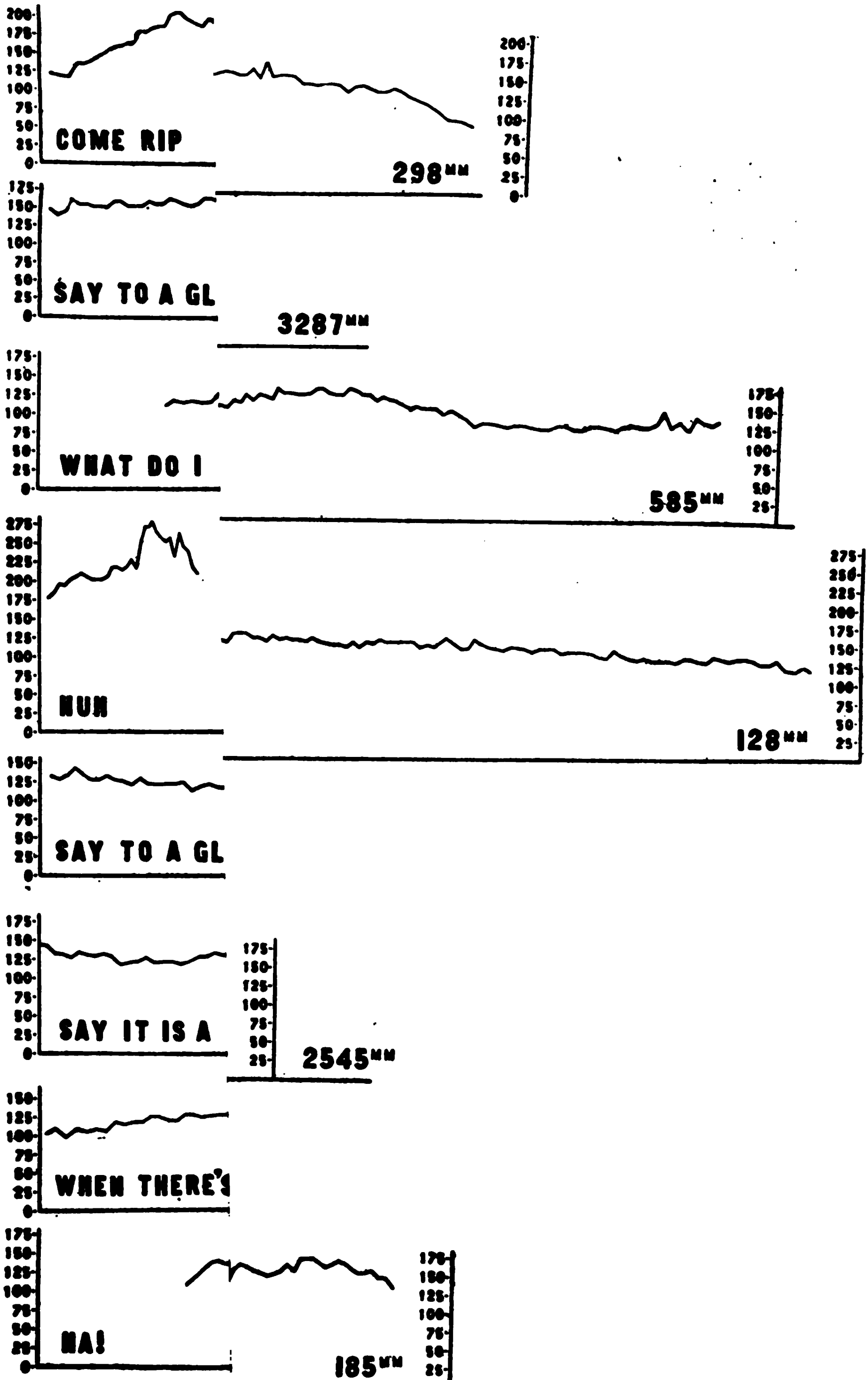


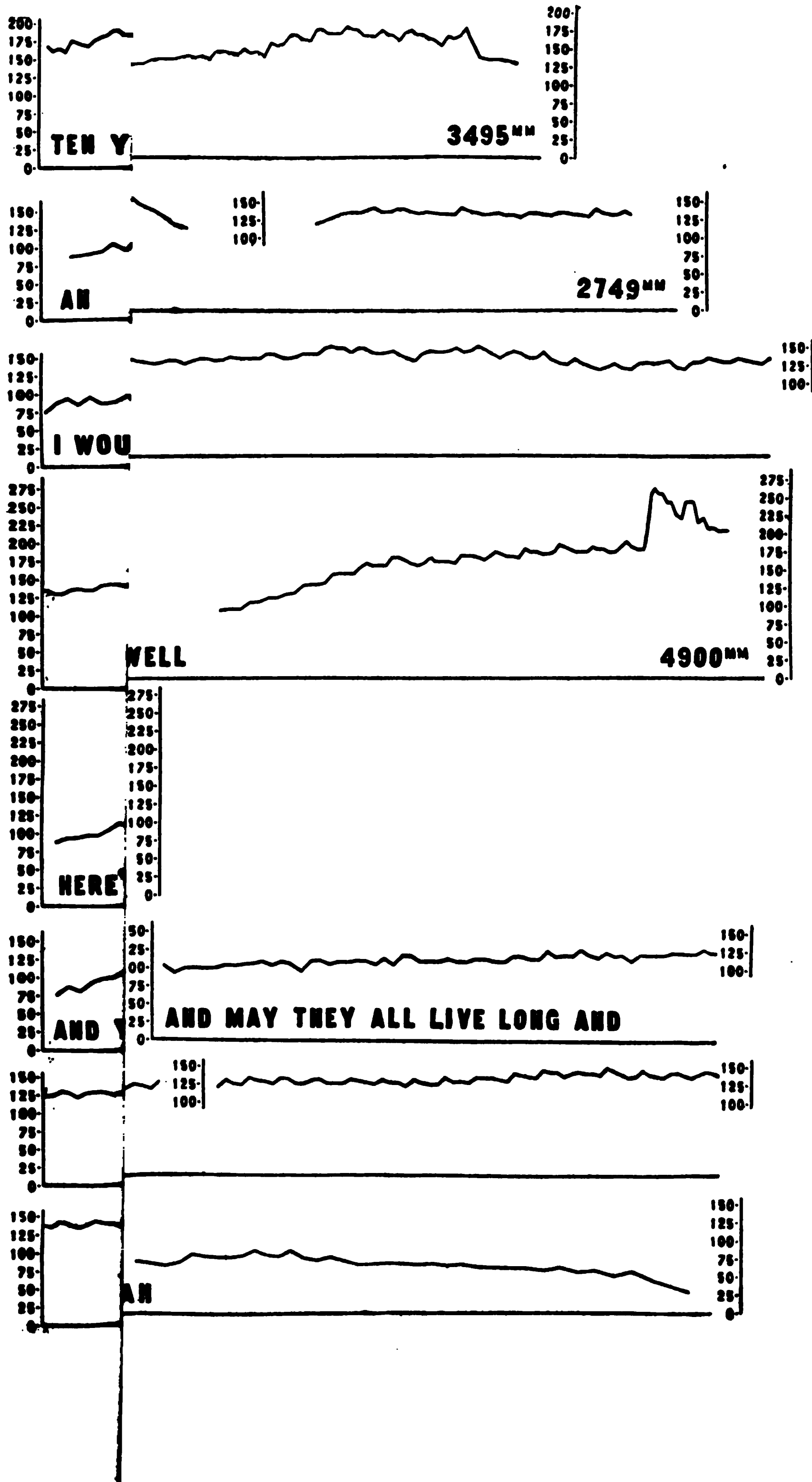
($1^{mm} = 0{,}0007^s$.)

P



TE X. *Rip Van Winkle's Toast*, by Joseph JEFFERSON. (Block VIII.)


COME RIP
298MM
SAY TO A GL
3287MM
WHAT DO I
585MM
HUH
128MM
SAY TO A GL
SAY IT IS A
2545MM
WHEN THERE'S
HA!
185MM


TEN Y
3495MM
AN
2749MM
I WOU
WELL
4900MM
HERE
AND Y
AND MAY THEY ALL LIVE LONG AND
AN